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The American Midland Naturalist

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VOL. XIII. MARCH, 1932 No. 2

PENNSYLVANIAN OSTRACODA

An Ostracoda Fauna of the Nowata Shale

H. N. CORYELL AND GUSTAVO A. OSORIO

INTRODUCTION

The collections from the Nowata Shale that formed the basis of this paper were made in 1930 by the senior author from the outcrop near Hughes Quarry about two miles northeast of Tulsa, Oklahoma. The microscopic study has been restricted to the Ostracoda even though Bryozoa, Brachiopoda, Pelecypoda and Foraminifera are present. All of these groups could be properly included in a paper on the microfauna of the Nowata Shale. The Ostracoda fauna consists of thirty species, six of which are new and described here for the first time. One other species appears under a new name. The formerly described species are included in the text with their original and synonymic references.

THE NOWATA SHALE

In northeastern Oklahoma the Nowata Shale consists of a series of shales interbedded with a few thin sandstone layers. A coal seam is present in some places. The formation has an average thickness of 600 feet near Tulsa. The name was taken from the town of Nowata, Oklahoma, near which there is an excellent exposure. The position of the Nowata Shale in the general plan of classification of the formations in north-

CORRELATION

eastern Oklahoma is shown in the accompanying tabulation on page 28.

The ostracode fauna of the Nowata Shale was compared with the species described from other places in the same geological province. On this basis a tentative correlation of the Nowata Shale has been made with other formations in Oklahoma and adjacent states. The following chart gives a list of the species that are present in the Nowata Shale and also occur in the formations with which the comparison was made (page 27).

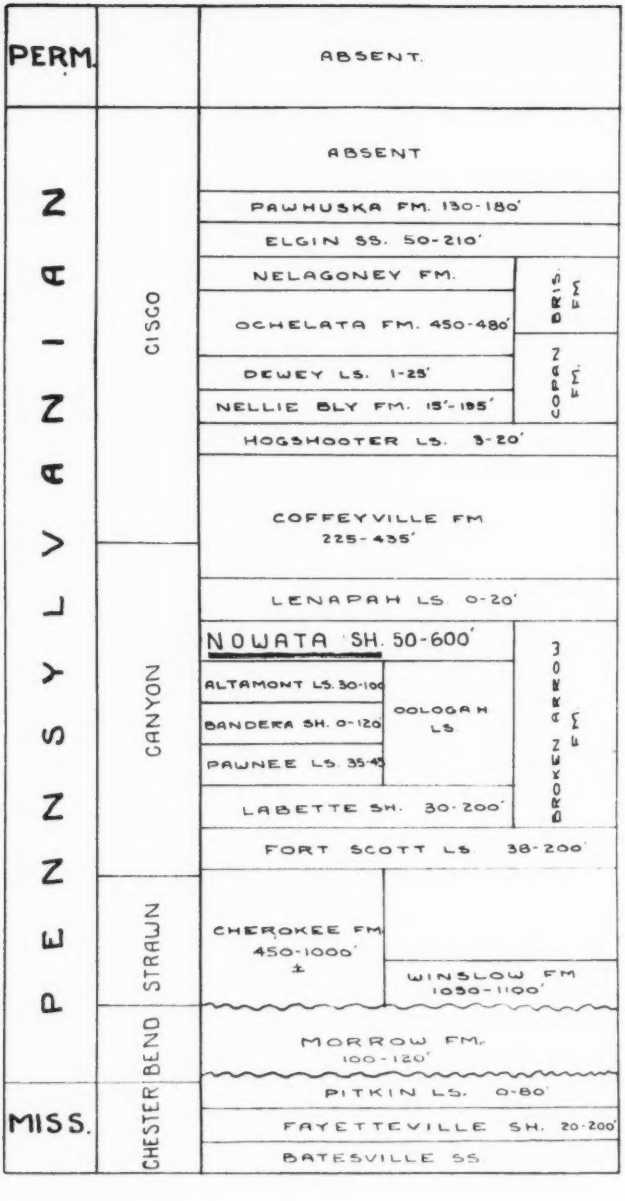
Fig. 1. An outline map of northeastern Oklahoma showing the location of Tulsa near which the collection from the Nowata shale was made.

Nowa

SPECIES	Nowata shale (N. E. Okla.)	Holdenville, Wetumka, Wewoka Frms. (Central So. Okla.)	Henrietta Fm. (Eastern Mo.)	Canyon Gr. (N. C. Texas)

Tabulation of the Species of Ostracodes in the Nowata shale and equivalent formations in other localities.

SPECIES	Nowata shale (N. E. Okla.)	Holdenville, Wetumka, Wewoka Fms. (Central So. Okla.)	Henrietta Fm. (Eastern Mo.)	Canyon Gr. (N. C. Texas)
Amphissites centronotus	X	X	X	
Amphissites girtyi	X	X	X	
Kirkbya clarocarinata	X		X	X
Ulrichia montosa	X	X	X	
Bairdia pompilioides	X	X		X
Bairdia hoxbarensis	X			X
Bairdia peracuta	X	X		
Bairdia menardensis	X	X		X
Bairdia moorei	X		X	
Bairdia crassa	X	X		X
Bairdia citriformis	X		X	
Bairdia nitida	X	X		X
Bairdia auricula	X	X	X	
Bythocypris pediformis	X	X	X	
Bythocypris rotunda	X	X		
Macrocypris menardensis	X			X
Healdia formosa	X	X		
Healdia elegans	X	X		
Cytherella calcar	X			X
Seminolites truncatus	X	X		
Seminolites elongatus	X	X		


PERM.
ABSENT.
PENNSYLVANIAN
MISS.
CISCO
CANYON
STRAWN
BEND
CHESTER
ABSENT
PAWHUSKA FM. 130-180'
ELGIN SS. 50-210'
NELAGONEY FM.
OCHELATA FM. 450-480'
DEWEY LS. 1-25'
NELLIE BLY FM. 15'-195'
HOGSHOOTER LS. 3-20'
COFFEYVILLE FM 225-435'
LENAPAH LS 0-20'
NOWATA SH. 50-600'
ALTAMONT LS. 30-100'
BANDERA SH. 0-120'
PAWNEE LS. 35-45'
OOLOGAH LS
LABETTE SH. 30-200'
FORT SCOTT LS 38-200'
CHEROKEE FM. 450-1000' ±
WINSLOW FM 1050-1100'
MORROW FM. 100-120'
PITKIN LS. 0-80'
FAYETTEVILLE SH. 20-200'
BATESVILLE SS
BRIS FM.
COPAN FM.
BROKEN ARROW FM.

CLASSIFICATION AND DESCRIPTION OF GENERA AND SPECIES

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA Latreille 1801
Family BEYRICHIIDAE Jones
Genus HOLLINELLA Coryell 1928
Genotype *Hollinella dentata* Coryell

Coryell, Jour. Paleo. vol. 2, 1928, no. 4, p. 378.
Moore, Dennison Univ. Bull. vol. 24, 1929, p. 102, 103.
Kellett, Jour. Paleo. vol. 3, 1929, no. 2, p. 196-200.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 56.

Hollinella nowataensis Coryell and Osorio n. sp.
Plate V, fig. 1.

Valves equal, large; length less than twice the height; hinge line straight; anterior end narrowly rounded; posterior end obliquely truncated dorsally; two nodes present on the surface of each valve and situated near the dorsal border; anterior node the larger and hemispherical; posterior node less conspicuous; the distance between the two nodes equal to about one-third the diameter of the anterior node; dorsal sulcus central, deep and extending down to the middle of the shell; ridge below the sulcus distinctly swollen; surface coarsely granulose; flange wide with the outer edge thickened especially along the postero-ventral margin.

Length, 1.32 mm. Height, 0.76 mm.

This species differs from similar forms in having a very large anterior node, a deep sulcus and the spacing of the nodes.

Holotype, Columbia University Paleo. Coll. No. 25211.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Hollinella inflata Coryell and Osorio n. sp.
Plate V, fig. 2.

Valves equal, subovate in latteral outline; length less than twice the height; hinge line straight; anterior end broadly rounded; posterior end dorsally truncated; anterior node ovate, larger than the posterior; the posterior node is small and less distinct; dorsal sulcus prominent, slightly posterior to the median portion of the shell; the swelling of the ridge

beneath the sulcus is not conspicuously distinct from the convexity of the valve; surface of the valve granulose; frill is thin, and narrow, the broadest portion near the posteroventral margin.

Length, 1.19 mm. Height, 0.71 mm.

This species differs from *H. nowataensis* in having a smaller shell and a ridge below the sulcus that is not distinctly separated from the convexity of the valve; the surface of the shell is less coarsely granulose.

Holotype, Columbia University Paleo. Coll. No. 25212.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Family KIRKBYIDAE Ulrich and Bassler 1906

Genus AMPHISSITES Girty 1910

Genotype *Amphissites rugosus* Girty

Girty, Annals N. Y. Acad. Sci., vol. 20, 1910, p. 235.
Knight, Jour. Paleo., vol. 2, 1928, no. 3, p. 258.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 63.

Amphissites centronotus (Ulrich and Bassler) 1906

Kirkbya centronota Ulrich and Bassler, Proc. U. S. Nat. Mus., vol. 30, 1906, p. 159, pl. 9, fig. 16, 17.
Amphissites centronotus Harlton, Jour. Paleo., vol. 1, 1927, no. 3, p. 207, pl. 32, fig. 10a, b.
Knight, Jour. Paleo., vol. 2, 1928, no. 3, p. 259, pl. 32, fig. 6a-e, pl. 34, fig. 2.
Delo, Jour. Paleo., vol. 4, 1930, no. 2, p. 160, pl. 12, fig. 9.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 66, pl. 5, fig. 4a-c.

This species differs from *A. girtyi* by the lack of the bar connecting the median node with the lower end of the posterior node.

Length, 0.95 mm. Height, 0.55 mm.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Amphissites girtyi Knight 1928

Amphissites girtyi Knight, Jour. Paleo., vol. 2, no. 1928, p. 260, pl. 32, fig. 7a-b; pl. 34, fig. 1.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 65, pl. 5, fig. 3.
Amphissites mesocosta Roth, Pub. Wagner Free Inst., vol. 1, 1929, p. 48, pl. 3, fig. 15.

Only one specimen was found of this species. Its preservation is not all that could be desired but it most probably belongs to Knight's species.

Length, 0.83 mm. Height, 0.38. Thickness, 0.32 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Genus KIRKBYA Jones 1859

Genotype *Dithyocaris permiana* Jones 1850

Jones, Tyneside Nat. Field Club, vol. 4, 1859, pt. 2, p. 129, 134.
Vine, Quart. Jour. Geol. Soc., vol. 38, 1882, p. 48.
Girty, Annals N. Y. Acad. Sci., vol. 20, 1910, no. 3, pt. 2, p. 233.
Eastman-Zittel, Text-book of Paleo., 1913, p. 728.
Ulrich and Bassler, Md. Geol. Surv., Silurian, 1923, p. 316.
Roth, Pub. Wagner Free Inst., vol. 1, 1929, p. 1-55.

Kirkbya clarocarinata Knight 1928

Kirkbya clarocarinata Knight, Jour. Paleo., vol. 2, no. 3, 1928, p. 258, pl. 32, fig. 2; pl. 33, fig. 2.
Harlton, Univ. Texas Bull. 2901, 1929, p. 152, pl. 2, fig. 3a, b.

This species resembles *K. scapula* Knight but is distinguished from it by its inner flange which is short and does not hide the outer flange.

Length, 1.07 mm. Height, 0.50 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Genus ULRICHIA Jones 1890

Genotype *Ulrichia conradi* Jones

Jones, Quart. Jour. Geol. Soc. London, vol. 46, 1890, p. 543.
Jones, Quart. Jour. Geol. Soc. London, vol. 49, 1893, p. 293.
Ulrich, Jour. Cincinnati Soc. Nat. Hist., vol. 13, 1891, p. 203.
Miller, N. Amer. Geol. and Paleont., 1892, p. 711.
Jones and Kirby, Trans. Royal Dublin Soc., vol. 4, ser. 2, 1898, p. 191, 192.
Bonnema, Min. Geol. Inst. Univ. zu Groningen, Mitteilungen, Band 2, Heft 1, 1909, p. 501.
Grabau and Shimer, N. Amer. Index Foss., vol. 2, 1910, p. 346.
Eastman-Zittel, Text-book of Paleo., 1913, p. 738.
Ulrich and Bassler, Md. Geol. Sur. Silurian, 1923, p. 301.

Ulrichia montosa Knight 1928

Urrichia montosa Knight, Jour. Paleo., vol. 2, no. 3, 1928, p. 252, pl. 32, fig. 1a, b; pl. 33, fig. 1.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 62, pl. 4, fig. 13.

Length, 1.30 mm. Height, 0.65 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Family BAIRDIIDAE Brady and Norman 1892

Genus SEMINOLITES Coryell 1928

Genotype, *Seminolites truncatus* Coryell

Coryell, Jour. Paleo., vol. 2, no. 2, 1928, p. 88.
Harlton, Amer. Jour. Sci., vol. 18, 1929, p. 265.
Delo, Jour. Paleo., vol. 4, no. 2, 1930, p. 173.

Seminolites truncatus Coryell 1928

Seminolites truncatus Coryell, Jour. Paleo., vol. 2, no. 2, 1928, p. 88, pl. 11, fig. 1.

Length, 0.72 mm. Height, 0.40 mm. Thickness, 0.29 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Seminolites extensus Coryell 1928

Seminolites extensus Coryell, Jour. Paleo., vol. 2, no. 2, 1928, p. 89, pl. 11, fig. 4.

Length, 0:69 mm. Height, 0.33 mm. Thickness, 0.28 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Seminolites elongatus Coryell 1928

Seminolites elongatus Coryell, Jour. Paleo., vol. 2, no. 2, 1928, p. 88, pl. 11, fig. 2.

This species differs from *Seminolites truncatus* in having a narrower and lower carapace and in the difference in the distribution of the pits.

Length, 0.66 mm. Height, 0.41 mm. Thickness, 0.26 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Genus BAIRDIA McCoy 1844

Genotype *Bairdia curta* McCoy 1844

McCoy, Synop. Carb. Foss. of Ireland, 1844, p. 164.
Jones, Monogr. Entom. Cret. Form. England, Paleo. Soc., 1849, p. 22.
Jones, Monogr. Tert. Entom. England, Paleo. So., 1851, p. 51.
Sars, Forhand. Vidensk.-Selskab, Christiania, Aar. 1865, p. 19.
Brady, Trans. Zool. Soc. London, vol. 5, 1866, p. 363.
Brady, Intellectual Oberver, vol. 12, 1867, p. 119.
Brady, Trans. Linn. Soc. London, vol. 26, 1868, pt. 2, p. 388.
Jones and Kirkby, Quart. Jour. Geol. Soc. London, vol. 35, 1879, p. 566.
Eastman-Zittel, Text-book of Paleo., 1913, p. 740.
Ulrich and Bassler, Md. Geol. Surv. Silurian, 1923, p. 319.
Doeglas, Overdruk int Wetenschappelijke Mededeelingen van den Mijnbouw in Nederlandsch-Indië, no. 17, 1931, p. 34.
Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 68.

Bairdia pompilioides Harlton 1928

Bairdia pompilioides Harlton, Jour. Paleo., vol. 2, no. 2, 1928, p. 140, pl. 21, fig. 13.

Harlton, Univ. of Texas, Bull. 2901, 1929, p. 154, pl. 2, fig. 7.

Bairdia subcitriformis Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 322, pl. 43, fig. 5a, b.

Length, 1.27 mm. Height, 0.66 mm. Thickness, 0.53 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia hoxbarensis Harlton 1927

Bairdia hoxbarensis Harlton, Jour. Paleo., vol. 1, no. 3, 1927, p. 211, pl. 33, fig. 12.

Harlton, Univ. of Texas Bull. 2901, 1929, p. 154, pl. 3, fig. 1a-d.

Bairdia altifrons Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 324, pl. 43, fig. 6a, b.

Length, 1.05 mm. Height, 0.61 mm. Thickness, 0.49 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia peracuta Warthin 1930

Bairdia peracuta Warthin, Okla. Geol. Surv. Bull. 53, 1930, p. 71, pl. 6, fig. 2a, b.

Length, 1.17 mm. Height, 0.49 mm. Thickness, 0.38 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia menardensis Harlton 1929

Bairdia menardensis Harlton, Univ. of Texas, Bull. 2901, 1929, p. 158, pl. 4, fig. 1a-d.

Delo, Jour. Paleo., vol. 4, 1930, no. 2, p. 164, pl. 12, fig. 16.

Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 71.

Length, 1.26 mm. Height, 0.68 mm. Thickness, 0.36 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia moorei Knight 1928

Bairdia moorei Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 318, pl. 43, fig. 1a-c.

Length, 1.27 mm. Height, 0.66 mm. Thickness, 0.62 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia crassa Harlton 1929

Bairdia crassa Harlton, Univ. of Texas, Bull. 2901, 1929, p. 158, pl. 4, fig. 3a-c.

Delo, Jour. Paleo., vol. 4, 1930, no. 2, p. 164, pl. 12, fi,g. 15.

Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 71, pl. 6, fig. 1a, b.

Delo, Contrib. in Geol., Wash. Univ. Studies, n. s. Sci. & Tech., 1931, no. 5, p. 49, pl. 4, fig. 9.

Length, 0.91 mm. Height, 0.56 mm. Thickness, 0.49 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia citriformis Knight 1928

Bairdia citriformis Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 321, pl. 43, fig. 4a-d.

Length, 0.78 mm. Height, 0.44 mm. Thickness, 0.40 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia blakei Harlton 1931

Bairdia nitida Harlton, Jour. Paleo., vol. 2, no. 2, 1928, p. 139, pl. 21, fig. 12.

Harlton, Univ. of Texas, Bull. 2901, 1929, p. 155, pl. 3, fig. 3a, b.

Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 72, p. 16, fig. 3a, b.

Bairdia nitida was preoccupied by Jones in 1879 for another species of the genus *Bairdia*.

Bairdia blakei Harlton, Jour. Paleo., vol. 5, 1931, no. 2, p. 163.

Length, 1.11 mm. Height, 0.72 mm. Thickness, 0.61 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Bairdia auricula Knight 1928

Bairdia auricula Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 319, pl. 43, fig. 3a, b.

Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 68, pl. 5, fig. 7a, b.

Bairdia dornickhillensis Harlton, (*Bairdia pottsvillensis* in explanation of plate 2) Amer. Jour. Sci., ser. 5, vol. 18, 1929, p. 268, pl. 2, fig. 12a, b.

Length, 1.33 mm. Height, 0.83 mm. Thickness, 0.53 mm. *Locality*, Hughes Quarry, Tulsa County, Oklahoma.

Genus BYTHOCYPRIS Brady 1880

Genotype *Bythocypris reniformis* Brady

Brady, Report Voy. Challenger, Zool., vol. 1, 1880, p. 45.

Jones & Kirkby, Ann. Mag. Nat. Hist., ser. 5, vol. 18, 1886, p. 250.

Jones & Kirkby, Quart. Jour. Geol. Soc. London, 1886, no. 42, p. 506.

Jones, Ann. Mag. Nat. Hist., ser. 5, vol. 19, 1887, p. 184.

Jones & Kirkby, Proc. Geol. Assoc., vol. 9, 1897, p. 510.

Ulrich, Jour. Cincinnati Soc. Nat. Hist., vol. 13, 1890, p. 196.

Miller, N. Amer. Geol. & Paleo., 1892, p. 706.

Ulrich, Geol. Surv. Minn., vol. 3, 1897, pt. 2, p. 686.

Eastman-Zittel, Text-book of Paleo., 1900, vol. 1, p. 646.

Eastman-Zittel, Text-book of Paleo., 1913, vol. 1, p. 740.

Grabau & Shimer, N. Amer. Index Foss., vol. 2, 1910, p. 365.
Ulrich & Bassler, Md. Geol. Surv., Silurian, 1923, p. 320.
Doeglas, Ostrakoden van N. O. Boreno Overduk int Wetenschappelijke van den Mijnbouw in Nederlandsch-Indië, no. 17, 1931, p. 34.

Bythocypris pediformis Knight 1928

Bythocypris pediformis Knight, Jour. Paleo., vol. 2, no. 4, 1929, p. 326, pl. 44, fig. 3.
Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 74, pl. 6, fig. 6a, b.

Length, 0.50 mm. Height, 0.22 mm. Thickness, 0.19 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Bythocypris fabulites Warthin (new name)

Bythocypris rotunda Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 74, pl. 6, fig. 7a, b.

Bythocypris rotunda Vanderpool was published for a Glen Rose species of Ostracoda in the Journal of Paleontology, vol. 2, 1928, p. 102, pl. 13, fig. 5, 6. This makes it nevessary to rename Warthin's species. Dr. Warthin has suggested the above name and permitted its publication here.

Length, 0.56 mm. Height, 0.25 mm. Thickness, 0.24 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Bythocypris gallowayi Coryell and Osorio n. sp.

Plate V, fig. 3.

Shell small, subtriangular in lateral view; dorsal border highly arched; greatest height a little posterior to the center; the antero- and postero-dorsal slopes slightly convex and nearly equal; the anterior end high and broadly rounded; posterior end less broadly rounded; ventral border concave anteriorly to the middle; overlap prominent along the dorsal border and tapers towards the ends; ventral overlap narrow; surface of the valves smooth.

Length, 0.72 mm. Height, 0.44 mm. Thickness, 0.35 mm.
Holotype, Columbia University Paleo. Coll. No. 25214.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

This species resembles *B. devonica* Ulrich but differs from it in having the anterior end higher and more broadly rounded.

Bythocypris gallowayi is named for Dr. J. J. Galloway.

Bythocypris faba Coryell and Osorio n. sp.
Plate 5, fig. 4.

Carapace subtriangular to subovate; dorsal border arched, greatest height near the middle of the valve; anterior dorsal slope broadly convex; posterior dorsal slope higher and slightly more narrowly convex; anterior end is more narrowly rounded than the posterior; ventral border concave near the center; ventral overlap greatest near the middle of the ventral margin and tapers out towards the extremities; the dorsal overlap is approximately the same width all along the dorsal edge and it also tapers out on the ends of the specimen; surface of the valves smooth.

Length, 0.94 mm. Height, 0.56 mm. Thickness, 0.37 mm.

Holotype, Columbia University Paleo. Coll. No. 25213.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

This species is larger and longer than *Bythocypris gallowayi*. It is less elongate than *Bythocypris sasakwaensis*.

Genus MACROCYPRIS Brady 1867
Genotype *Cythere minna* Baird

Brady, Intellectual Oberser, vol. 12, 1867, p. 119.
Brady, Trans. Linn. Soc. London, vol. 26, 1868, p. 391.
Brady, Report Challenger Exped., Zool., vol. 1, 1880, p. 40.
Jones & Kirkby, Proc. Geol. Soc. London, vol. 9, 1886, p. 510.
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Miller, N. Amer. Geol. and Paleo., 1889, p. 709.
Eastman-Zittel, Text-book of Paleo., vol. 1, 1900, p. 646.
Eastman-Zittel, Text-book of Paleo., vol. 1, 1913, p. 740.
Ulrich & Bassler, Md. Geol. Surv., Silurian, 1923, p. 321.

Macrocypris menardensis Harlton 1929

Macrocypris menardensis Harlton, Univ. of Texas, Bull. 2901, 1929, p. 161, pl. 4, fig. 7a, b.
Delo, Jour. Paleo., vol. 4, no. 2, 1930, p. 174, pl. 13, fig. 10.

Length, 0.81 mm. Height, 0.36 mm.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Genus HEALDIA Roundy 1926
Genotype *Healdia simplex* Roundy

Roundy, U. S. Geol. Surv., Prof. p. no. 146, 1926, p. 8.
Harlton, Amer. Jour. Sci., vol. 18, ser. 5, 1929, p. 260.

Healdia formosa Harlton 1928

Healdia formosa Harlton, Jour. Paleo., vol. 2, no. 2, 1918, p. 135, pl. 21, fig. 7.

Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 77, pl. 6, fig. 13a, b.

Healdia limacoidea Knight, Jour. Paleo., vol. 2, no. 4, 1928, p. 333, pl. 44, fig. 5.

Length, 0.66 mm. Height, 0.38 mm. Thickness, 0.30 mm.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Healdia elegans Warthin 1930

Healdia elegans Warthin, Okla. Geol. Surv., Bull. 53, 1930, p. 76, pl. 6, fig. 11a, b.

Length, 0.77 mm. Height, 0.43 mm. Thickness, 0.39 mm.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Healdia tulsaensis Coryell and Osorio n. sp.

Plate V, fig. 5.

Carapace small, subovate in lateral view; greatest length of the valves is about the mid-height of the specimen; dorsal margin arched; greatest height slightly posterior of the center; ventral margin only slightly convex; anterior end narrowly rounded and much lower than the posterior; spines are not present on the posterior ridge which extends upward and backward from the ventral border to the dorsal border; the posterior ridge is flush with the anterior convexity of the valves; posterior margin rounded dorsally and slightly truncated ventrally; the left valve overlaps and is so large that it can be seen all around in a right lateral view; postal dorsal slope contact depressed but not conspicuous in lateral view.

Length, 0.47 mm. Height, 0.27 mm. Thickness, 0.22 mm.

Holotype, Columbia University Paleo. Coll. No. 25216.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

This species differs from *Healdia nucleolata* Knight in having a left valve that can be seen all around when observed in right lateral view and in the position of the posterior ridge.

Healdia arcuata Coryell and Osorio n. sp.

Plate V, fig. 6.

Carapace small, subtriangular; dorsal border highly arched; greatest height a little posterior to the middle; anterior dorsal

slope is slightly convex; posterior dorsal slope strongly concave; anterior end rounded, truncated ventrally and lower than the posterior end; posterior dorsal angle obtuse; ventral border straight; posterior ridge indistinct; posterior spines prominent; the distance between the two spines is equal to about one-half of the posterior height of the valves; left valve is the larger and overlaps the right slightly all around except on the post-dorsal slope; surface of the valve smooth.

Length, 0.72 mm. Height, 0.45 mm. Thickness, 0.29 mm.

Holotype, Columbia University Paleo. Coll. No. 25215.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

This species is easily distinguished by the conspicuously concave post-dorsal slope, the position of the large spines and the high angulate dorsal margin.

Genus ACRATIA Delo 1930

Genotype *Acratia typica* Delo

Delo, Jour. Paleo., vol. 4, no. 2, 1930, p. 174.

Acratia magna Delo 1930

Acratia magna Delo, Jour. Paleo., vol. 4, no. 2, 1930, p. 175, pl. 13, fig. 13.

Length, 1.34 mm. Height, 0.55 mm. Thickness, 0.57 mm.

Locality, Hughes Quarry, Tulsa County, Oklahoma.

Family CYTHERELLIDAE Sars 1865

Genus CYTHERELLA Jones 1849

Genotype *Cytherina ovata* Roemer 1840

Jones, Monogr. Entom. Cret., Paleontogr. Soc., 1848, p. 6, 7, 9, 14, 28.
Bosquet, Mem. Couron. Acad. Belg., vol. 24, 1852, p. 91.
Reuss, Neues Jahrb. Min., 1853, p. 676.
Bosquet, Mem. Commis. Carte Geol. Neerland, vol. 2, 1854, p. 53.
Reuss, Deutsch, akad. Wiss. Wien., vol. 7, 1854, p. 140.
Reuss, Zeitsch. Deutsch Geol. Gesell., vol. 7, 1855, p. 277.
Bonnemann, Zeitsch. Deutsch. Geol. Gesell., vol. 7, 1855, p. 353.
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Jones, Kirkby & Brady, Monogr. Entom. Carbonif. Form., Paleo. Soc., 1884, p. 58-80.

Zittel, Handbook Paleontology, 1885, p. 556.
Jones, Kirkby & Brady, Proc. Geol. Assoc. London, vol. 9, 1886, p. 502.
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Vogdes, Ann. N. Y. Acad. Sci., vol. 5, 1884, p. 4.
Miller, N. Amer. Geol. & Paleo., 1st ed., 1892, p. 707.
Ulrich, Geol. Surv. Minn., vol. 3, 1897, (1894), pt. 2, p. 684.
Koken, Die Leitfossilien, Leipzig, 1896, p. 40.
Eastman-Zittel, Text-book of Paleo., vol. 1, 1900, p. 646.
Grabau & Shimer, N. Amer. Index Foss., vol. 2, 1910, p. 366.
Eastman-Zittel, Text-book of Paleo., vol. 1, 1913, p. 740.
Ulrich & Bassler, Md. Geol. Surv., Silurian, 1923, p. 321.

Cytherella calcar Harlton 1928

Cytherella calcar Harlton, Jour. Paleo., vol. 2, no. 2, 1928, p. 141, pl. 21, fig. 16a, b.
Harlton, Univ. Texas Bull. 2901, 1929, p. 161, pl. 4, fig. 9.

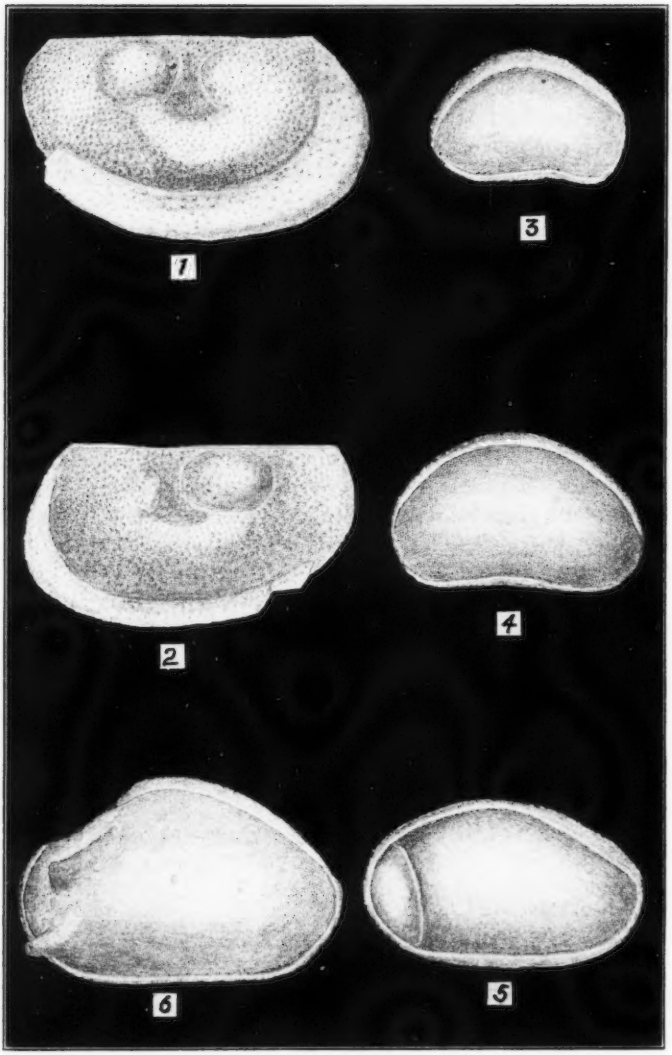
Length, 0.52 mm. Height, 0.26 mm. Thickness, 0.39 mm.
Locality, Hughes Quarry, Tulsa County, Oklahoma.

Columbia University,
New York, N. Y.

PLATE V.

Fig. 1. Hollinella nowataensis n. sp. X40 (Left valve)
Fig. 2. Hollinella inflata n. sp. X40 (Right valve)
Fig. 3. Bythocypris gallowayi n. sp. X40 (Right valve)
Fig. 4. Bythocypris faba n. sp. X40 (Right valve)
Fig. 5. Healdia tulsaensis n. sp. X90 (Right valve)
Fig. 6. Healdia arcuata n. sp. X80 (Right valve)

PLATE V.



BORING SPONGES IN THE DEVONIAN OF IOWA

CARROLL LANE FENTON AND MILDRED ADAMS FENTON

I. THE GENUS CLIONOLITHES CLARKE[1]

The generic name *Clionolithes* was proposed by Clarke for various types of fossil borings, all of which he attributed to species whose habits were allied to those of the modern monactinellid genus *Cliona*. In the discussion preceding his proposal of a distinctive name for the fossils, Clarke specially mentioned the Silurian *Vioa prisca* McCoy[2], but did not designate that species as the genotype. This was fortunate, for in 1921 we find him stating that "we are convinced that such tubes as were indicated by McCoy are referable to the worms," or Annelida, and that "we propose to apply to all of them the designation *Palaeosabella prisca* (McCoy) . . .[3] Although Clarke states on an earlier page[4] that "the generic designation *Clionolithes* . . . was based on the form described by McCoy," and that limitation of the genus to sponges "may not be in precise accord with proper nomenclatorial procedure," the limitation is made, and *Clionolithes* remains in the 1921 paper as a sponge, not an annelid.

Although little inclined to take liberties with rules of nomenclature, we consider that in the present instance the course taken by Clarke was proper—even though our reasons differ considerably from his. Confining our attention to the original publication of *Clionolithes*, we find nothing but the order of specific diagnoses which gives preference to *Vioa prisca* McCoy as a possible genotype, and nothing which in-

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[1] N. Y. State Mus., 61st Ann. Rep., vol. 1, p. 168, 1908. Adv. sheets 4th Ann. Rep. Director Science Division, p. 27, 1908.

[2] Systematic Description British Palaeozoic Fossils, etc., p. 260, pl. 1B, figs. 1-1a, 1885.

[3] Organic Dependence and Disease: their Origin and Significance, p. 91, 1921. This publication also appears as Bul. 221-2 of the N. Y. State Museum.

[4] Op. cit., p. 85.

dicates that the interpretation of the name was based upon the characters of that species. Indeed, just the reverse seems to be true, for of the species described, *Clionolithes priscus* (McCoy), *C. radicans*, *C. reptans* and *C. palmatus* (the latter three new), only the type specimens of McCoy's species show its essential characters. Chief emphasis is placed upon C. *radicans*, which Clarke again illustrates in some detail in 1921, whose nature is markedly different from that of *"C." priscus*.

It is for these reasons that we follow Clarke in applying *Clionolithes* to those Devonian fossils which give evidence of origin through the boring action of monactinellid sponges. In order to make our usage more clear, we shall attempt a formal definition of these traces, and shall select a genotype. For guidance in the latter, we turn to Article 31, paragraphs g, k and n of the International Rules of Zoological Nomenclature,[5] which define the conditions under which genotypes may be made by subsequent designation, suggest that in cases such as this preference be given to "species still remaining in the original genus," and recommend that preference be given the one which is best described or best figured. On these grounds we select *Clionolithes radicans* Clarke as genotype, and with it in mind offer the following generalized diagnosis:

Genus **Clionolithes** Clarke

Genotype: *Clionolithes radicans* Clarke

Clionolithes Clarke, N. Y. State Mus., 61st Ann. Rep., vol. 1, p. 168, 1908. (Includes *Vioa prisca* McCoy.)

Clionolithes Clarke, Organic Dependence and Disease, etc., pp. 85-88, 1921; also Bul. 221-2, N. Y. State Mus., pp. 85-88, 1921. (Excludes *Vioa prisca* McCoy.)

Description.—Boring, presumably monactinellid sponges whose fossils consist of tubes excavated in the shells of brachiopods, molluscs and other organisms. Characteristically, these tubes radiate from a common center, which may be single and pronounced (as in *C. radicans*), or multiple and indistinct, as in *C. irregularis* n. sp. In some species, the

[5] As reprinted in Proc. Biol. Soc. Washington, vol. 39, pp. 84-85, 1926.

tubes are expanded into palmate channels, which commonly terminate in minute, radiating or irregularly branching tubes. In others the tubes are errant, coiled, crossing and anastomosing in patterns which almost obscure the centers of radiation. So far as can be told, the true tubes are small, generally being less than 0.5 mm. in diameter.

Remarks.—Although such forms as *C. reptans* Clarke depart widely from the characters of the genotype, *C. radicans* Clarke, they preserve sufficient trace of centers of radiation to justify their retention in the genus—especially since such forms do not come to notice in the Devonian of Iowa.

Occurrence.—All known species of *Clionolithes* have been found in the Devonian, but it seems probable that the genus is not restricted to that system. No careful search has been made for it in either younger or older formations.

Clionolithes hackberryensis (Thomas)

Plate VI, Figs. 1-6.

Cliona hackberryensis Thomas, Bull. Lab. Nat. Hist. State Univ. Ia., vol. 6, p. 165, plate, 1911.

Cliona hackberryensis Fenton and Fenton, Contr. Mus. Geol. Univ. Mich., vol. 1, p. 23, pl. 1, fig. 8, 1924.

Description.—Sponge represented by combined radiating and ramifying burrows which begin as rosette-like extensions from a central vertical burrow or pit. In this stage, indicated by Figs. 3 and 4, the horizontal tubes are very small, 0.1 to 0.2 mm. apparently being the typical diameter.

As the sponge increases in size, the borings grow larger—0.2 to 0.35 mm.—and one or two from each center achieve dominance, commonly obscuring the others, and spread out into a ramifying or reticulate system of tubes which branch and unite with marked angularity, and lose all trace of radial arrangement. Most of them extend parallel or obliquely to the surface; a few extend vertically, and pierce it. So far as can be found, none of the parallel or oblique tubes send out vertical branches which pierce the shell, as is common in the modern *Cliona*, and some of its fossil relatives.

Remarks.—The late Dr. A. O. Thomas, author of *Cliona*

hackberryensis, referred the radiating early stages of his species to *Clionolithes radicans* Clarke. Although unwilling to follow him in this, we were unaware of the significance of these early burrows at the time of writing our account of the larger Hackberry fauna, and hence limited our description of *C. hackberryensis* to specimens of the type considered by Dr. Thomas, allowing the species to remain in the genus *Cliona*. The specimens here illustrated, which both show the true relationship of apparently distinct forms, and place the species in the genus *Clionolithes*, were secured in 1925, while collecting for the Carnegie Museum.

Occurrence.—Throughout the Spirifer zone of the Hackberry stage, and perhaps in lower beds as well. Specially common on shells of *Strophonella* and *Schizophoria*, and on the gastropod, *Floydia*.

Plesiotypes.—Nos. 4804-4809 Carnegie Museum.

Clionolithes irregularis n. sp.

Plate VII, Fig. 7.

Description.—Sponge represented by slender, thread-like, tubular borings which apparently radiate from central, vertical borings. Unlike *C. hackberryensis*, this species does not form rosettes in early stages, nor is there distinguishable suppression of certain tubes. The tubes branch abundantly, and though occasionally curved, commonly run in nearly straight lines from division to division, forming a highly angular network beneath the surface. Their diameters range from 0.3 to 0.5 mm.; their lengths, to 10 mm.

Remarks.—From the specimens at hand, it seems that *C. irregularis* commonly burrowed into the brachial valves of living brachiopods, excavating tubes which for the most part were parallel to the surface of the shell. Vertical tubes, however, are not rare.

Occurrence.—Lower and middle portions of the Cedar Valley stage, especially in the so-called Acervularia and Raymond Quarry beds of Blackhawk County, Iowa, and in apparently equivalent strata near Iowa City.

Holotype.—No. 84693 U. S. National Museum.

Clionolithes fossiger n. sp.

Plate VII, Figs. 4-6.

Description.—Sponge represented by straight or (more commonly) flexuous borings which branch irregularly, yet preserve traces of radial plan. The larger ones are the more nearly straight; their diameters range from 0.4 to 0.7 mm. and their lengths to 14 mm. From centers along these larger tubes others, 0.1 to 0.3 mm. in diameter arise. These divide further, and commonly unite with tubes extending from other main channels, in a pattern which somewhat suggests that of *C. reptans* Clarke.

Remarks.—This species differs from other members of the genus known from the Devonian of Iowa in that it is found only in hard, calcareous casts or internal molds of pelecypods, and apparently excavated tubes in those casts rather than in the shells themselves. From comparison with the habits of certain modern and Cretaceous Clionidae, which merely pierce the shell surface and excavate broad, imbricating channels deep within it, we assume that the tubes present in these casts merely represent the innermost level of excavation, those in the pelecypod shell itself having vanished with it. Since the shells of dead pelecypods fill rapidly with sediment, and since the calcareous muds of the Hackberry stage apparently hardened with considerable rapidity, this filling doubtless offered a medium for the sponges which was quite as satisfactory as the actual substance of the shell.

The preference of *Clionolithes fossiger*, for molluscs as hosts, seems clear—and of molluscs, pelecypods were most favored. The tubes are commonest in *Paracyclas validalinea* Webster, but are present also in *Grammysia* (?) *dubia* F. and F., *Paracyclas sabini* White and others.

Occurrence.—Spirifer zone of the Hackberry stage, north-central Iowa. Probably in the Owen substage as well.

Holotype.—No. 4811; *Paratypes.*—Nos. 4810 and 4812, Carnegie Museum.

II. CLIONOIDES, NEW GENUS

Numerous specimens of thick-shelled *Atrypae* from the Cedar Valley strata of central Iowa bear tubes or borings which from their size and regularity at first were thought to be the work of annelids. They show, however, characters which link them closely with the excavations made by modern members of the poriferid family Clionidae,[6] so that they seem properly to be included in that group. In these very characters, however, they differ from the Devonian genus *Clionolithes* Clarke to a degree which seems to make the erection of a new genus imperative if they are to be taxonomically recognized. In recognition of its similarity to the existing genus *Cliona*, we give it the designation *Clionoides*, while the genotype is named *C. thomasi* in honor of the late Dr. A. O. Thomas, of the State University of Iowa, who first described boring sponges from the upper Devonian rocks of his home state.

Clionoides nov. gen.

Genotype: *Clionoides thomasi* n. sp.

Description.—Boring, presumably monactinellid sponges whose fossils consist of tubes excavated in the hard parts (chiefly shells) of other organisms. Characteristically, these tubes are widely spaced, branched and irregularly disposed, with only moderate curvature and no trace of radial arrangement. They communicate with the outer surface by means of round perforations, whose distribution along the tubes is uncertain. Probably they roughly correspond to others, penetrating the inner surface, which are closely spaced throughout the length of each tube. It is these perforations which most clearly link the genus with *Cliona*, and distinguish it from annelid borings of comparable size.

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[6] Thus designated by Topsent in his *Contribution a l'Etude des Clionides*, Arch. Zool. Expérimentale et Générale, 2e ser., vol. 5 bis, suppl., 4e mem., 1887. Ridley and Dendy, in Rep. Sci. Results Voy. H. M. S. Challenger, vol. 20, p. 227, 1887, use the family name Suberitidae.

Clionoides thomasi n. sp.

Plate VII, Figs. 1-3.

Description.—Tubular burrows, flexuous, straight or irregularly branching, whose diameters range from 0.5 to 1.5 mm., with an average of about 1 mm. From the tubes extend round perforations which are irregularly grouped in some instances, but on the whole are closely spaced throughout the length of the tubes. Branching infrequent; imbrication rare.

Remarks.—In general, the tubes are larger in specimens of *Atrypa waterlooensis* Webster, and related forms, from Waterloo, Iowa, than they are in similar shells from other localities. The fact that they are generally, if not always, excavated in the brachial valve seems to indicate that the host lay in the mud with that valve uppermost, and that the sponge was able to burrow only in the hard material of the shell. The species is known only from the shells of these large *Atrypae*, associated *Spiriferi*, corals and stromatoporoids apparently being unwelcome as hosts.

Occurrence.—Devonian (Cedar Valley) beds at Brandon, Waterloo, Littleton and other localities in north-central Iowa. Not known from the upper Cedar Valley (Bloody Run) of Floyd and Greene counties.

Holotype.—No. 84700; *Paratypes.*—No. 84641 U. S. National Museum.

III. TOPSENTIA CLARKE: ITS APPARENT SYNONYMY AND NATURAL HISTORY

We already have commented on the fact that Clarke, in defining the genus *Clionolithes*, included in it the borings described by McCoy as *Vioa prisca*, and a number of others that he identified with them. Later, he removed these from this genus because of his belief that they were the work of annelids, to which he gave the name *Palaeosabella*.

In this second publication, Clarke also proposed the genus *Topsentia* for apparent sponge borings found in stromatoporoids of Cedar Valley age. We quote his description of genus and species:

"Of entirely different type and of much greater size is a

perforating sponge that we observe in the Middle Devonian Stromatoporas of Iowa. In this there is a large spherical central body from which stout cylindrical arms radiate into the coral substance. The formation of the tunneling appears to begin with the gradual burial of the round centrum with its branches and the subsequent excavation of additional tunnels by later outgrowths of the colony. These sponges have been found both as depressions at the surface of the coral and as completely buried bodies within the coral substance and revealed only by cutting.

"This parasitic sponge we shall designate *Topsentia devonica.*"[7]

The essential characters of *Topsentia*, therefore, are the central, generally spheroidal cavity, and the radial perforations that Clarke calls arms. In most specimens, these perforations do not branch; though generally of uniform size, a few are found to enlarge distally. If one overlooks differences of size—the central cavity of *Topsentia* has been found to exceed 10 mm. in diameter—the whole structure strikingly suggests *Vioa prisca* McCoy, of which the original figures are reproduced in Fig. 1 of Plate IX.[8]

In his first description of *Clionolithes*, Clarke reproduces McCoy's Fig. 1 with some simplification, yet he seems to ignore the prominent central cavity by his statement that McCoy "illustrated under the name *Vioa prisca* a series of simple straight club-shaped casts of borings in the shell substance of a pelecypod . . . of the upper Siluric." He also says that "The straight clavate tubes of *Clionolithes priscus* usually

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[7] Organic Dependence and Disease, etc., p. 88, 1921; also Bul. 221-2, N. Y. State Museum. The generic name honors Emile Topsent, French authority on boring sponges.

[8] McCoy, p. 260, pl. 1B. Although generally quoted as British Palaeozoic Fossils, with McCoy as sole author, this volume bears the following title: "A Synopsis of the Classification of the British Palaeozoic Rocks, by the Rev. Adam Sedgwick, M. A., F. R. S. . . . . with a Systematic Description of the British Palaeozoic Fossils in the Geological Museum of the University of Cambridge, by Frederick McCoy, F. G. S., Hon. F. C. P. S.," etc.; London and Cambridge, 1855. The description of *Vioa prisca* is found under that of *Pterinea demissa* (Conrad), in whose shell the borings occur.

originate at the edge of a dead shell and expand gently inward; probably the sponge rested at the club-shaped extremity of the hole, drawing water currents in to itself . . . This form, *C. priscus*, was quite common in the late Siluric and very abundant throughout the Devonic."[9]

In removing *Vioa prisca* from the sponges, Clarke refers only to "straight, subclavate fillings," and "simple wormborings . . . found in many sorts of solid calcareous organic masses in the Paleozoic rocks."[10] In the paragraph containing the name *Paleosabella* (there is no description), only such borings and curved ones receive mention. Says Clarke, "we propose to apply to all of them the designation *Paleosabella prisca* (McCoy) disregarding differences of size, which are often obvious, and of curvature, which are slight. We give abundant illustrations of these occurrences and in the explanations to them point out features of special interest."[10]

The first of these illustrations which are to establish the genus, *sans* diagnosis, appears on the following page. It shows several nearly straight, apparently non-clavate borings in a shell of the brachiopod *Leptostrophia*, from the lower Devonian Grand Grève limestone of Quebec. Other figures on pages 93 to 103 show varied tubules, some straight, some clavate, some intricately branching. At least two tubes turn through 115 to 120 degrees, to form sharply acute angles; others are abruptly recurved or coiled, involving departures from straightness well exceeding 200 degrees. Not until page 103 is reached do we find McCoy's original figure—still more simplified.

Were we to interpret Clarke's apparent intention rather than his practice, we should be forced to conclude that *Paleosabella*, being monospecific, has *Vioa prisca* McCoy as its genotype; and that since that species seems to possess the essential characters of *Topsentia*, *Paleosabella* becomes a probable synonym of the genus described three pages before

[9] N. Y. State Museum, 61st Ann. Rep., vol. 1, p. 168, 1908; also Adv. Sheets 4th Ann. Rep. Director Science Division, p. 27, 1908. This is merely an advance printing, with separate pagination, of the same paper and plates.

[10] Organic Dependence and Disease, etc., p. 91, 1921.

it. This would leave the American borings figured by Clarke as *Clionolithes* and *Paleosabella prisca* without designation, since they cannot be reconciled with McCoy's description and figures. Certainly they are not to be transferred to *Topsentia*.

We have seen, however, that in proposing the name *Paleosabella*, Clarke considered only his American material, and both by implication and statement of characters excluded *Vioa prisca* McCoy. Seven figures of Devonian borings precede the reproduction of McCoy's figure; the explanation of that figure makes no mention of "features of special interest," and it is followed by nine other figures representing Devonian borings. We conclude, therefore, that *Paleosabella* is based upon *P. prisca* Clarke, not *Vioa prisca* McCoy; that the genus is without genotype, implied or described; that if used at all (and it seems to be useful) it should be based upon borings comparable to those shown in Clarke's Fig. 77, page 92, of *Organic Dependence and Disease*. It is not a synonym of *Topsentia*.

With this disposition of nomenclatorial problems, we proceed to descriptions and comments of the genus *Topsentia* and its species:

Genus **Topsentia** Clarke

Genotype *Topsentia devonica* Clarke

Description.—Boring, presumably monactinellid sponges whose fossils consist of cavities and tubes or channels, generally excavated in stromatoporoids or other organisms, but found also in sediments. The cavity is central, spheroidal or irregularly ovoid when fully developed, but begins as a cup-shaped excavation. From it radiate simple or branching tubes and channels, some of which enlarge distally. Size of excavations highly variable; as preserved, commonly incomplete.

Remarks.—We agree with Clarke that excavation began with the central cup or cavity, from which radial extensions were developed. We do not think, however, that as growth progressed the cavity was abandoned, since its enlargement is roughly proportionate to the size and development of the

tubes. Each system of cavities seems to have been made by a continuous sponge colony as in the living genus *Cliona*, and we consider that the tubules were occupied by members still connected with the central paragastric cavity. Further comment on the habits of the genotype is given under *T. devonica*.

Occurrence.—Topsentia is most abundant in the Cedar Valley formations of Iowa, and less so in the Shellrock stage above them. It apparently extends downward into the Silurian. No systematic search for representatives has been made.

Topsentia devonica Clarke

Plate VIII; Plate IX, Fig. 2.

Topsentia devonica Clarke, Organic Dependence and Disease, etc., p. 88, figs. 73-75, 1921; also Bul. 221-2, N. Y. State Museum, 1921.

Description.—Central cavity irregularly spheroidal when complete, 1 to 10 or more mm. in diameter. Radial tubes generally simple but in some cases branched, not markedly clavate, and of diameters ranging from 0.5 to 3 mm.

Remarks.—The stromatoporoids in which excavations of *T. devonica* are common are nodular or irregularly massive forms, most of which grew directly upon surfaces formed by calcareo-clastic sediments, with which they formed massive beds often miscalled reefs. Superficially, these stromatoporoids appear to have grown in the upright manner of many sponges—the attitude in which (for convenience) Fig. 2 of Plate IX is posed. The exposed lamellae upon their surfaces, however, show that the stromatoporoids generally were prostrate—a conclusion borne out by the direction of their astrorhizal (or paragastric) systems. When the substratum was hard, growth was flattened; when soft, symmetrical. In many cases, it seems to have been both, the expanding colonies growing over partly buried masses of earlier ones and the areas of sediment between. Such growth gave rise to irregular masses such as the one shown in Fig. 2 of Plate VIII. The specimen of Clarke's Fig. 73 seems to be the terminal portion of a colony comparable to that of Plate IX, Fig. 2. His Figs. 74 and 75 show colonies similarly prostrate, that did not reach large size, and its consequent irregularity.

Thus we find that large excavations made by *Topsentia devonica* generally lie upon the under surfaces of their hosts; in the rare instances in which they are completely enclosed, that enclosure seems to have been accomplished by secondary development of lamellae—perhaps following shifting in the position of the colony through wave action. Although such action is not indicated by storm rollers or ripple marks, it is suggested by the worn condition of some of the stromatoporoids themselves, and the fragmental condition of most of the associated brachiopods.

It seems that in living stromatoporoids, *Topsentia* began its excavations at or near the edge of the colony, whose continued enlargement buried the sponges. In keeping with this, we find that the largest borings commonly are nearest the center of growth, and that there is a marked (though not uniform) decline in size marginally. The largest excavation figured by Clarke lies almost at the base of the colony. Incomplete central cavities beneath large stromatoporoids may mean that the sponges bored partly in the substratum, while tubes without attendant cavities (seen best in Plate IX, Fig. 2) probably indicate that the major growth of the sponge was in the substratum.

The most marked departures from these general limitations of habit are seen in stromatoporoids which have been eroded and rolled prior to fossilization. In them, the lamellae are incomplete, the upper surfaces worn, and the borings of *Topsentia* distributed without regard to original orientation of the stromatoporoids. One rolled specimen (No. 37039 Walker Museum) shows incomplete excavations upon its upper surface; another (No. 37038 Walker Museum) is deeply pitted on all surfaces, and seems to have been reduced to a bare core of the original by the boring sponges and annelids. One of the *Topsentia* colonies shows a secondary cavity on one of the radial canals similar to that seen in Plate VIII, Fig. 1: but from it subsidiary canals radiate. We have noticed no case, however, in which large cavities are thus connected.

Occurrence.—Topsentia devonica is common in the several stromatoporoid beds of the upper Cedar Valley stage in Floyd and other counties of north-central Iowa. It also has been

found in the Shellrock stage, on massive stromatoporoids. Its borings have not been noted in corals.

Plesiotypes.—Nos. 37036-37039 Walker Museum, University of Chicago.

Topsentia (?) prisca (McCoy)

Plate IX, Fig. 1.

Vioa prisca McCoy, in Sedgwick and McCoy, Synopsis of the Classification of British Pal. Rocks, etc., p. 260, pl. 1B, figs. 1-1a, 1855.

Description.—"A specimen [of Pterinea demissa] from the Malverns shews several small holes in the shell, from each of which radiate specimens of a small *Cliona*, or *Vioa*, burrowing into the substance of the shell, simply dichotomous at an angle varying from 45° to 70°; the branches are rounded, two or three lines long, obtuse and slightly dilated at the tip, with a diameter of one-third of a line. As this is the oldest known boring sponge, I have named it *Vioa prisca*, and figured it Pl. I. B. fig. 1." (McCoy).

Remarks.—Our reasons for placing this species in *Topsentia* have been given. We question the reference because we have not seen the type specimens.

Occurrence.—Upper Silurian, the Malverns, England. Not known from North America.

A NEW SPECIES OF CLIONA FROM THE CRETACEOUS OF NEW JERSEY

CARROLL LANE FENTON AND MILDRED ADAMS FENTON

While studying the borings of *Clionolithes* and *Clionoides* from the Devonian of Iowa, considerable use was made of modern shells bored by *Cliona* (probably two or three species), and of similarly bored shells of *Gryphaea* and *Exogyra* collected from the Navesink greensands of the New Jersey Cretaceous.

As work progressed, it became plain that these Cretaceous traces, although closely related to such living species as *Cliona celata* Grant, manifest certain peculiarities which are striking and constant. Although the biologic significance of those peculiarities is not wholly clear, it seems that the purposes

of paleontology and stratigraphy will be best served if their possessors are designated a distinct species, of which a description is presented here.

Cliona cretacica n. sp.

Plate VII, Figs. 8-9.

Description.—Boring, clionoid sponges whose fossils consist of excavations, and casts (or internal moulds) of excavations in the shells of molluscs. At the surface these excavations are represented by round perforations 0.6 to 1.4 mm. in diameter; in greensand casts (best seen in partly corroded shells) these perforations are found to communicate with a system of imbricating, fused and expanded channels which terminate internally in perforations which, as a rule, are smaller and less numerous than those in the outer surface. The diameters of the channels range from 0.8 to 2.5 mm. in regions where they are not fused, or expanded into chambers. They seem not to form ovate or spheroidal cavities, and as a rule lie along fairly definite planes which roughly parallel the surface of the shell.

Remarks.—The large size and regularity of pattern shown by the tubes of *Cliona cretacica* serve to differentiate the species from its present congeners in the northern Atlantic. Whether differences between the types and other borings from the New Jersey Cretaceous demand specific or subspecific distinction is not clear; they may be of environmental origin.

Cliona cretacica has been noted only in the shells of *Gryphaea* and *Exogyra*—a circumstance perhaps to be explained that most other contemporaneous molluscs whose shells were large enough to harbor this sponge are preserved only as casts or internal moulds. Massive shells of *Gryphaea* contain the largest and most regular colonies.

Occurrence.—Navesink greensands of New Jersey, especially near New Egypt, Birmingham and nearby towns. Probably wide-spread upon the Coastal Plain, in formations other than the Navesink.

Holotype.—No. 8184; *Paratype*, No. 8185, New Jersey State Museum.

PLATE VI.

FIGURES

1–6. *Clionolithes hackberryensis* (Thomas)

1–2. Surfaces of two pedicle valves of *Strophonella hybrida* H. & W., showing typical perforations made by this species. Hackberry stage, Spirifer zone, Bird Hill, west of Rockford, Iowa. (4804-4805 Carnegie Mus.)

3. A worn valve of *Spirifer* cf. *euginus* C. L. F., bearing radiating channels resembling those of *C. radicans* Clarke. Hackberry stage, Spirifer zone, Rockford, Iowa. (4806 Carnegie Mus.)

4. Similar channels upon the pedicle valve of *Schizophoria iowensis* (Hall). x2. Hackberry stage, Spirifer zone, Rockford, Iowa. (4807 Carnegie Mus.)

5–6. Brachial valves of *Schizophoria iowensis* (Hall) showing union of radiating and normal channels of *C. hackberryensis* (Thomas). Hackberry stage, Spirifer zone, Rockford, Iowa. (4808-4809 Carnegie Mus.)

7. *Clionolithes radicans* Clarke. Portion of the shell of *Atrypa* sp., bearing typical channels of this species. After Clarke.

PLATE VI.

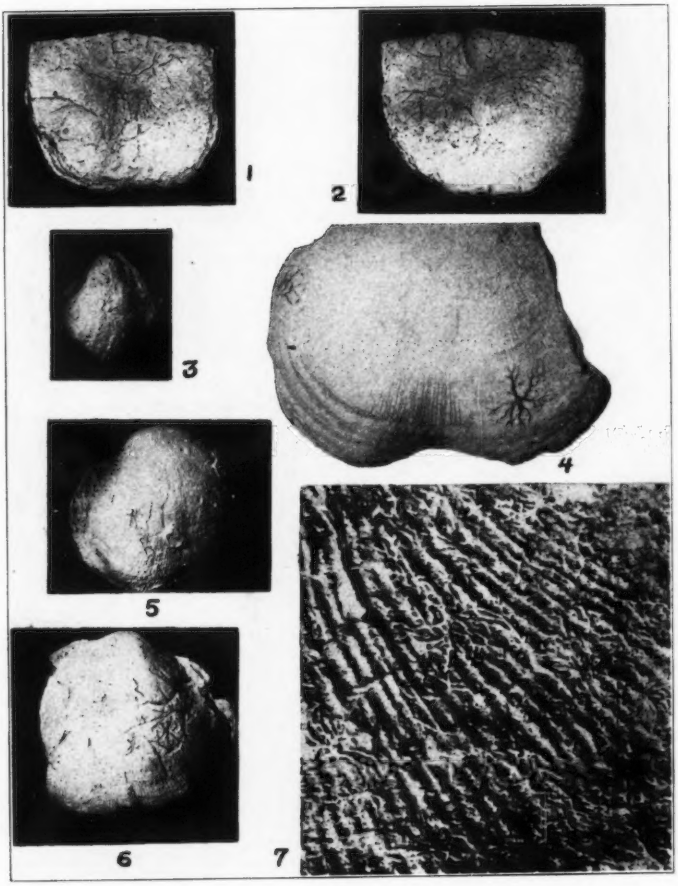


PLATE VII.

FIGURES

1–3. *Clionoides thomasi*, n. sp.

1. Typical borings of this species, upon the brachial valve of *Atrypa waterlooensis* Webster. Note the fusion of tubes. Cedar Valley stage, Waterloo, Iowa. (84641a U. S. Nat. Mus.)

2. Brachial valve of *Atrypa waterlooensis* Webster, showing linear perforations from the tubes. Cedar Valley stage, Waterloo, Iowa. (Holotype, 84700 U. S. Nat. Mus.)

3. A similar specimen, showing both tubes and perforations. (84641b U. S. Nat. Mus.)

4–6. *Clionolithes fossiger*, n. sp.

4–5. Casts of *Paracyclas validalinea* Webster bearing the tubes of this species. Hackberry stage, Spirifer zone, Juniper Hill, west of Rockford, Iowa. (4810-4811 Carnegie Mus.)

6. Similar tubes in a cast of *Paracyclas sabini* White. Locality as above. (4812 Carnegie Mus.)

7. *Clionolithes irregularis*, n. sp.
Ramifying tubes in the brachial valve of *Atrypa* sp. Cedar Valley stage, Blackhawk County, Iowa. (84693 U. S. Nat. Mus.

8–9. *Cliona cretacica*, n. sp.

8. Shell of *Exogyra* bearing the perforations of this species. (8185 N. J. State Mus.)

9. Partly dissolved shell of *Gryphaea* showing casts of the tubes of this typical Navesink species. Both specimens from the Navesink formation, Bruere farm, north of New Egypt, N. J. (Holotype, 8184 N. J. State Mus.)

PLATE VII.

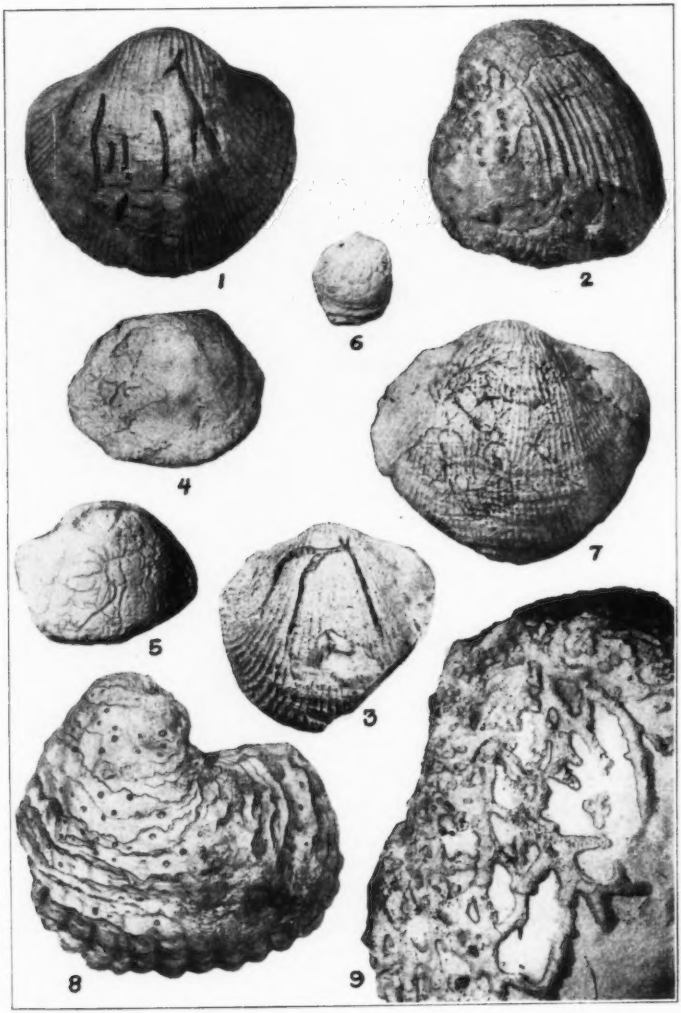


PLATE VIII.

FIGURES

1–2. *Topsentia devonica* Clarke

1. System of canals and cavities on lower surface of a stromatoporoid from the Shellrock stage (Aulopora shale) at Nora Springs, Iowa. Note small secondary cavity on one of the canals. Reduced.

2. Numerous cavities and canals on under surface of a large stromatoporoid from the second stromatoporoid bed at Bloody Run, near Charles City, Iowa; Cedar Valley stage. x 0.3. (37037, Walker Mus.)

PLATE VIII.

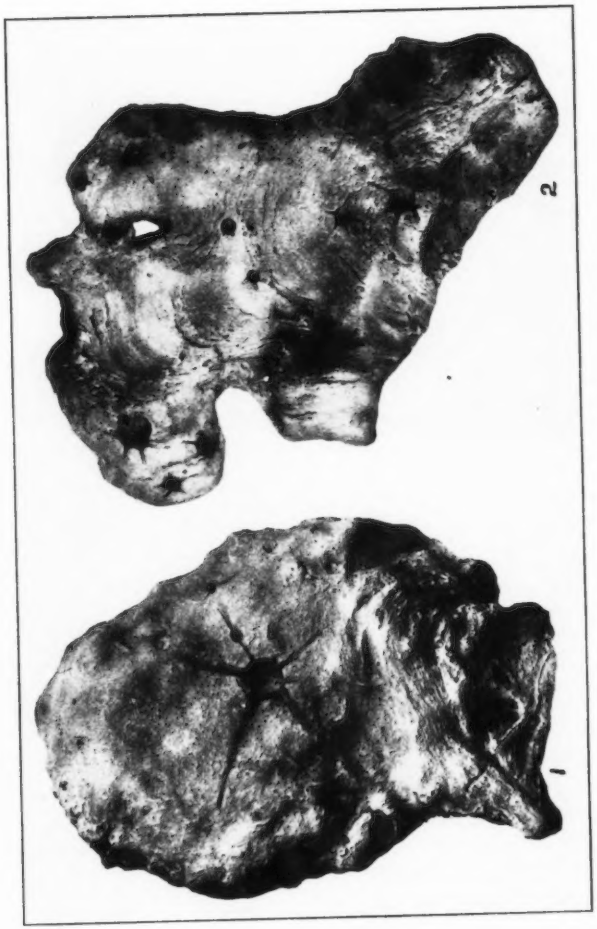


PLATE IX.

1

2

FIGURES

1. *Topsentia* (?) *prisca* McCoy
McCoy's figures, showing the characteristic central cavity, not mentioned by Clarke.
1

2. *Topsentia devonica* Clarke

Numerous small cavities in a prostrate stromatoporoid of Cedar Valley age, from the second stromatoporoid bed at Bloody Run, near Charles City, Iowa. x 0.3. (37036, Walker Mus.)

ORIENTATION AND INJURY IN THE GENUS ATRYPA

CARROLL LANE FENTON AND MILDRED ADAMS FENTON

I. ORIENTATION

The question of life-like orientation of Paleozoic brachiopods, especially those which are members of the order Telotremata, is one to which paleontologists have given comparatively little attention. The position of the fossils themselves rarely furnishes a clue to their attitudes or orientation during life, nor does the outline of the shell render one position obviously necessary, as it so commonly does among pelecypods and snails. Information must be sought in structures such as the beak and pedicle opening, and in secondary features such as distortion or erosion of valves, and the distribution of attached organisms whose growth evidently took place during the lives of their hosts.

The difficulty is further enhanced by the fact that the modern Telotremata which are most easily studied inhabit environments very different from those of their familiar Paleozoic relatives. *Terebratalia* and *Terebratulina*, for instance, possess species which inhabit depths so slight that they may be dredged with ease, and even examined in place when their homes are laid bare by low tides; but their environments, transformed into indurated rock, would be the coarsest of littoral conglomerates, in which few if any autochthonous fossils might be found. If there are modern Telotremates which dwell upon shallow, muddy sea-bottoms comparable to those which evidently were prevalent in the Paleozoic, their habits are not mentioned in available literature.

Living forms do aid, however, to this extent: they show that the normal attachment of a telotremate brachiopod whose pedicle opening is not blocked, is that shown in Fig. 1. Whether the valve of attachment is dorsal or ventral in actual position seems to make little difference; in many individuals, attached to vertical or overhanging faces of rock, it is neither. In general, it seems that brachiopods inhabiting very shallow water occupy the under surfaces of rocks or other objects,

and so tend to have the pedicle valve in ventral position. Those of deeper waters (in Puget Sound, 20 to 140 meters), show a reverse tendency, since large rocks are scarce and the substratum consists of small pebbles, fragments of shells, and even massed living organisms such as colonies of *Modiolus*. In intermediate depths, and in regions of piled rocks of considerable size, all sorts of positions are taken, as chance and the substratum dictate.

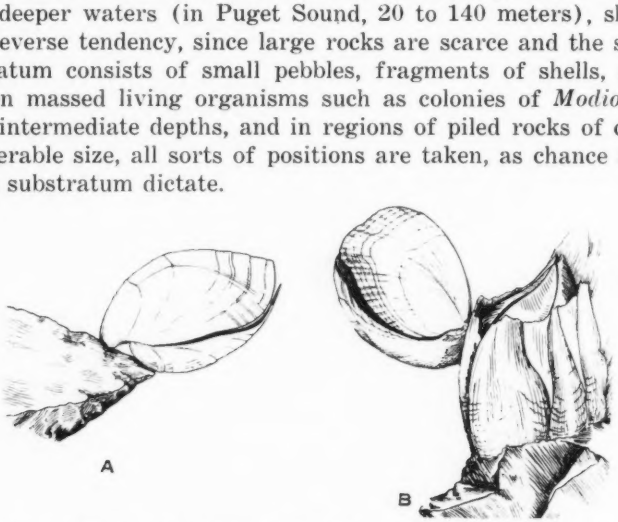


Fig. 1. Modern brachiopods showing variation in orientation. A, *Terebratalia transversa* (Sowerby) from a depth of about 125 meters, near Friday Harbor, Wash.; pedicle valve dorsal in position. B, *T. transversa caurina* (Gould), depth 80-90 meters, near Friday Harbor, Wash. Both specimens lived below the zone in which light is the determining factor in orientation. Slightly enlarged.

In the Paleozoic genus, *Atrypa*, the environment presupposes growth with the pedicle valve directed upward, or even dorsal, since the shells are found in sediments which preserve few bases of attachment other than bryozoans, small corals, and fragments of shells. Yet it seems clear, from the shape of the valves during adult and gerontic stages, that such a position could not be maintained throughout life, however general it may have been in youth. The chief purposes of this paper are to trace the changing orientation of *Atrypa* during normal life, and to review some of the evidence, both normal and pathologic, by means of which changes in orientation are determined.

The young *Atrypa* is a typical Telotremate, in that it has a pedicle valve which is longer than the brachial, with a beak

which projects prominently. The deltidial plates, generally broken or hidden in the adult, are united and exposed: the foramen is open, and of moderately large size when compared with that of the entire shell. The pedicle which emerged from it seems to have performed its normal function of attachment, for specimens are not rare in which the beak is distorted and the umbo of the brachial valve either flattened or worn by contact with the substratum. Whether posed as shown, or otherwise, there seems no doubt that the normal, immature *Atrypa* rested with the valves in the positions, relative to the substratum, in which they are shown in Fig. 2.

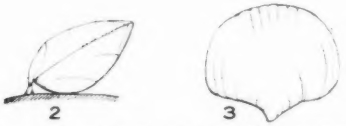


Fig. 2. Orientation of a neanic specimen of *Atrypa*, considerably enlarged.

3. Advanced neanic specimen of *Atrypa waterlooensis* Webster, n. var., showing distortion of the pedicle beak. In this specimen, the brachial umbo is flattened and slightly worn. Cedar Valley (Devonian), Waterloo, Iowa.

In *Atrypa marginalis* Dalman, and similar species, this normal relationship of the pedicle valve to the substratum seems to have been maintained throughout life. So long as the beak of the pedicle valve remained clear of the brachial umbo, and that umbo remained so moderately convex that the pedicle might retain its hold upon the substratum, the organism had no difficulty in retaining its early—we even may say primitive—orientation, whose similarity to that of the modern *Terebratalia*, and such Paleozoic genera as *Cranaena*, is shown in Figs. 1-2.

In *Atrypa imbricata* Sowerby, however, other conditions prevailed during ephebic and gerontic growth. The brachial valve became highly convex, its umbo filling most of the cardinal area of the other valve, whose beak thus became even more closely appressed than its own incurvature made necessary. As is indicated by Fig. 4, attachment could have been maintained only by distortion of the pedicle into a position which, if at all possible, would have greatly hampered movement of the valves. It seems necessary to conclude that the

pedicle became obsolete or lost, and that the shell turned over and ultimately came to rest upon its pedicle valve.[1]

Turning to more familiar *Atrypae*, commonly grouped as *A. reticularis* (Linnaeus) and *A. aspera* Schlotheim even though several valid species have been proposed, we find that reversal comparable to that in *A. imbricata* seems to have been the rule. Only in a few forms, such as *A. owenensis* Webster, of the Hackberry (Devonian), does the pedicle valve remain the longer and the more convex; in the majority, it becomes relatively shallow, while the brachial valve attains a high convexity which sends its beak and umbo (posterior to the fulcrum of the hinge) deep into the delthyrium of the opposite valve. In many cases, the pressure exerted by the brachial umbo seems to have been great enough to break away the delitidal plates and much of the cardinal area, especially during gerontic growth. An example of such pronounced incurvature is shown in Fig. 5.

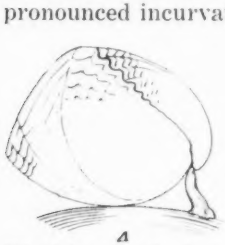


Fig. 4. *Atrypa imbricata* Sowerby, posed as would be necessary if the pedicle functioned throughout life.

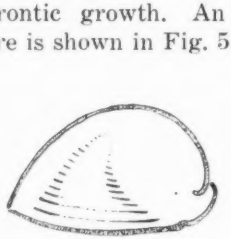


Fig. 5. *Atrypa nuntia* Hall and Whitfield, middle Devonian, Clark County, Indiana. Natural section, showing inward tilting of the brachial beak and umbo.

As the brachial valve enlarged, the relatively small, fleshy pedicle must have become non-functional or (in shells whose areas were filled) even disappeared. Even where the latter did not take place, the pedicle was too small to hold the shell in place during ephebic and gerontic growth. In *Atrypa in-*

[1] In gross morphology, extremely gerontic shells of *Atrypa imbricata* closely resemble those of *Rhynchotrema capax*, of the Richmond, whose orientation-sequence probably conformed to the one outlined for this type of *Atrypa*. Less gibbous species of *Rhynchotrema* probably retained their primitive orientation. As is shown by a survey of orientation in *Spirifer* (*sensu lato*), now underway, orientation in Paleozoic brachiopods is primarily determined by gross shell morphology, not by specific, generic or even ordinal relationships.

dependencis Webster, for instance, a shell 41 mm. wide and 27.5 mm. thick is provided with a foramen about 0.3 mm. in diameter. When we note that this specimen once possessed lamellar alations which probably doubled its present width, increased its length by half, and proportionately increased the weight of the shell, the discrepancy becomes more striking. Even if we postulate a certain swelling of the pedicle beyond the foramen, it still does not seem to have attained a size sufficient to effectively anchor so considerable a mass. As a matter of fact, the thin edges of the foramen do not indicate that the pedicle of *Atrypa*, like that of *Lingula*, increased greatly in size beyond the confines of the shell.

It seems probable, therefore, that the pedicle became nonfunctional during the ephebic life of most Silurian and Devonian *Atrypae*, and that in a considerable number of them it disappeared. To what extent it was reduced in those species in which the foramen remained open below the brachial valve cannot be told; perhaps in some of them the pedicle was resorbed or lost, and the foramen closed by a tough sheath of flesh, comparable to that closing the delthyrium of *Terebratalia*, beneath the pedicle.

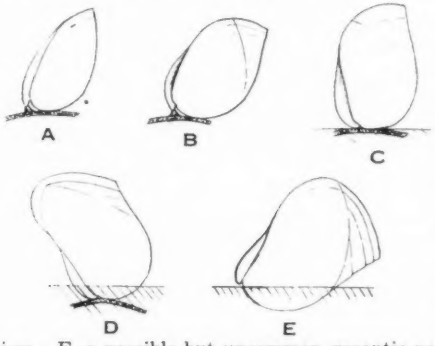


Fig. 6. Changes in orientation in a deeply sinuate *Atrypa*. A-C, successive stages in which the pedicle could function: the difficulty of maintaining the last is obvious unless the pedicle was very strong. D, a gerontic stage showing approximate degree of burial necessary to hold the shell in position; such burial probably would kill the organism. E, a possible but uncommon gerontic position, with pedicle obsolete and brachial umbo imbedded in mud.

There are two conceivable positions which the *Atrypa* shell may have occupied once the hold of the pedicle was lost. In some instances, it may have sunk into the soft mud of the bottom and remained there, with the pedicle valve uppermost.

More commonly, however, the growth of the brachial valve must have turned the shell first into an upright position, and ultimately onto the pedicle valve. The contrast between these two positions, and the stages by which the second—and more general—one would have been reached, are shown in Figs. 6 and 7.

Fig. 7. Probable adult and gerontic orientation of large, sinuate *Atrypae*. A, *Atrypa trowbridgei* F. and F.; B, *Atrypa lineata* Webster, Devonian (Cedar Valley) of Iowa. Note that in both, lamellae lift the antero-lateral margin well above the bottom muds. It is probable that shells such as *A. nuntia* H. and W. (Fig. 5) were similarly elevated anteriorly.

The shape of the valves in gerontic *Atrypae* gives some evidence as to the functional possibility of the two positions. As may be seen in Fig. 6A, life in the mud, with the shell resting on the brachial valve, would not be impossible so long as the fold remained moderate, and the lamellae did not reach great size. But it is characteristic of many gerontic *Atrypae* that both of these conditions are violated: the fold becomes pronounced and the notch for the ligual extension deep, while lamellae develop greatly. As is shown by Figs. 6B, C and D, the poise of a highly convex *Atrypa* would become increasingly uncertain unless the pedicle umbo were so deeply imbedded in mud as to threaten the life of the organism. In addition to this difficulty, it seems that with extreme gerontic incurving of the brachial beak, the effectiveness of the pull of the diductor muscles upon the pedicle valve would be considerably reduced. Even though a brachiopod does not open its valves widely, it must keep them open for long periods, so that any such difficulty would have serious disadvantage.

In contrast with this, we find that a shell in the position indicated in Fig. 7 would derive profit from at least two of the features so disadvantageous in the other. A marked fold and lingual extension would lift the opening above the mud, and in a measure protect it from unwelcome particles, while

the lamellae, extending at angles from the body of the shell, would further raise it from the bottom. Unless some accident removed them, the shell hardly could sink to the position indicated in Fig. 5, and such accidents seem not to have been common. Finally, although no advantage would result from a weakening of the muscular pull upon the pedicle valve, it would do no harm; and the more motile valve would be given all possible freedom. The readiness with which modern brachiopods close their valves when irritated seems to indicate the need for such freedom; and in the specimens that we have studied, the brachial valve is the one that moves.[2]

This change in orientation of the adult *Atrypa* seems to be reflected in the position of boring and attached organisms found upon it. If the pedicle valve permanently remained uppermost, the brachial sinking deeper and deeper into the mud, the former should bear the greater number of attached forms, such as *Spirorbis*, *Hederella*, *Crania*, and young corals. Were the brachial valve permanently dorsal in position, just the reverse should be true; while reversal in orientation should result in a shift—ectoparasites upon the pedicle valve in young stages, and the brachial in late ones, with a secondary appearance of boring forms antero-marginally during gerontic growth. Also, if comparisons with living brachiopods and sessile molluscs are valid, the greatest number of

[2] We do not advance these advantages and disadvantages of position and function as examples of adaptation in the Darwinian, Lamarckian or even the Buffonian sense. In so far as there is any value in the sequence of orientation outlined here, it seems to us an inevitable consequence of morphologic change. That races were eliminated because they made the morphologic change without the corresponding one in position we cannot admit, since it does not seem that one could have been done and not the other. That there was any special advantage in the new mode of life adopted by these more specialized groups of *Atrypae* seems equally doubtful, since other brachiopods (quite as successful as they) retained the primitive orientation,—a fact which opposes both Darwinian and Lamarckian interpretations. It does not even seem possible to invoke the "pre-adaptation" hypothesis of Cuenot (*La genese des especes animales*, 1917; commented upon by Lindsey, *Problems of Evolution*, pp. 133, 214, 1931) without modification to a degree which seems inconsistent with Cuenot's original statement. We prefer to leave the matter without what doubtless would be a wholly premature attempt at explanation.

attached forms should appear upon the brachial valve, which by hypothesis was exposed for a longer time and offered a larger, less irregular surface for attachment.

On few specimens has it been possible to distinguish clearly a marked sequence in the attachment of ectoparasites, such as has been outlined from hypothesis. It seems clear, however, that those of the pedicle valve are concentrated into two regions: that of the umbo, and the antero-lateral and lingual areas. This is true even of boring forms, such as annelids and sponges, though they appear infrequently upon the pedicle umbo.

Even more striking is the concentration of borers and ectoparasites upon the brachial valve. One example of it is shown in Plate X, Fig. 6; others appear on Figs. 1-3 and 7 of Plate VII, dealing with Devonian boring sponges. By reference to them and to Figs. 1-7 of Plate VI, it will be seen that in most cases the sponges are most abundant upon the valves which both in anatomy and umbonal erosion appear to have occupied the dorsal position—whether the brachial, as in *Atrypa*, *Strophonella* and *Schizophoria*, or the pedicle, as in *Spirifer*.

To summarize: The anatomy of typical members of the genus *Atrypa* belonging to the groups of *A. imbricata*, *A. "reticularis"* and *A. aspera* indicates that they spent their early shelled stages attached to objects upon the sea bottom, in attitudes adoped by modern *Telotremata* of similar habit, with the pedicle valve generally dorsal in position. With continued growth the pedicle became functionless or was lost, the shell was rotated upon the highly convex brachial umbo until it fell upon its depressed pedicle valve, and there it lay through the remainder of normal life. Settling into the mud was prevented by spines, alations or both, which seem to have been most highly developed upon the anterior portion of the pedicle valve. In most cases the reversal of position occurred prior to the establishment of many attached or boring animals upon the surfaces of the valves, and such organisms are concentrated upon regions which would be freely exposed during ephebic and gerontic existence.

II. INJURY

For shells of their size, thickness and lack of delicate projections, brachiopods of the Linnean species *Atrypa reticularis* (linneon of Lotsy; phratry of C. L. Fenton) show a remarkable number of serious injuries to the mantle and shell. In some the valve is sharply broken, its fractured edges either projecting or partially covered by subsequent deposits. In many cases, such injuries affect both valves, though rarely equally; and they are found upon either the brachial or the pedicle valve. Examples are illustrated in Plate X, Figs. 5 and 7.

Injuries which appear to have affected the mantle, thus interfering with normal growth, yet did not fracture the shell, are even more common, and also are illustrated on Plate X. Commonly they result in deep indentations accompanied by bifurcation of plications within the affected area. Generally, they affect both valves; in young stages they tend to be most serious upon the pedicle valve; in advanced ones, upon the brachial. They commonly occur upon the fold or lingual extension, and in a surprising number of instances they appear in pairs. This last feature is best known in Figs. 9-10 of Plate X, but appears also upon Figs. 3 and 8.

Less striking, but more general, are mere distortions, caused by pressure of the nearly motionless shell against adjoining objects. Such distortion is common in modern brachiopods of firm attachment, and may be taken to indicate similar fixation in many fossil species.[3]

In interpreting these injuries, it is easiest to begin with this third group, since they are most obviously related to position and growth, and to injuries in familiar living brachiopods. As might be inferred, the most serious are those which originated relatively early in life—presumably, during the period of fixation by the pedicle. Such injuries, both symmetrical and isolated, appear in Figs. 3 and 8, Plate X; the symmetrically paired injuries shown in Fig. 10 also may

[3] Injuries comparable to these, but in no case paired, are described by C. L. Fenton in *Studies of Evolution in the Genus Spirifer*, pp. 107-109, 1931. In one case a fragment of bryozoan is surrounded by the shell of an otherwise normal *Spirifer*.

be of this type, though they seem to have broken the shell. Marked distortion, such as is shown in Fig. 2, however, is not rare in ephebic stages, so that firm fixation of the shell may be inferred, even after the pedicle became non-functional. Such fixation would be afforded by the lamellae, which were well developed even upon such apparently smooth species as *Atrypa nuntia*.[1] It seems clear that such lamellae, projecting into a muddy bottom, or partly covered with accumulating

[1] This form, abundantly illustrated by Hall (Pal. N. Y., vol. 4, pl. 51, figs. 10-24, 1867) was named *A. reticularis nuntia* by Hall and Whitfield in the 24th Ann. Rep. N. Y. State Cab. Nat. Hist., p. 199, 1872. It is here regarded as a valid species, characteristic of the Interior Hamilton, of which *A. reticularis ventricosa* of Hall and Whitfield, *loc. cit.* is a subspecies or variant.

PLATE X.

FIGURES

1. *Atrypa* sp., undescribed, showing injury to the mantle resulting in a deep fold in ephebic shell growth. Devonian (Cedar Valley), near Waterloo, Iowa. (84646 U. S. Nat. Mus.)

2. *Atrypa nuntia* H. & W., showing typical deformation of the shell without discernible injury. Devonian (Hamilton: Sellersburg?), Charleston, Ind.

3–4. *Atrypa waterlooensis* Webster, var. undescribed. Deformed specimens, of types common in this species. Devonian (Cedar Valley), Waterloo, Ia. (4772 and 4771 Carnegie Mus.)

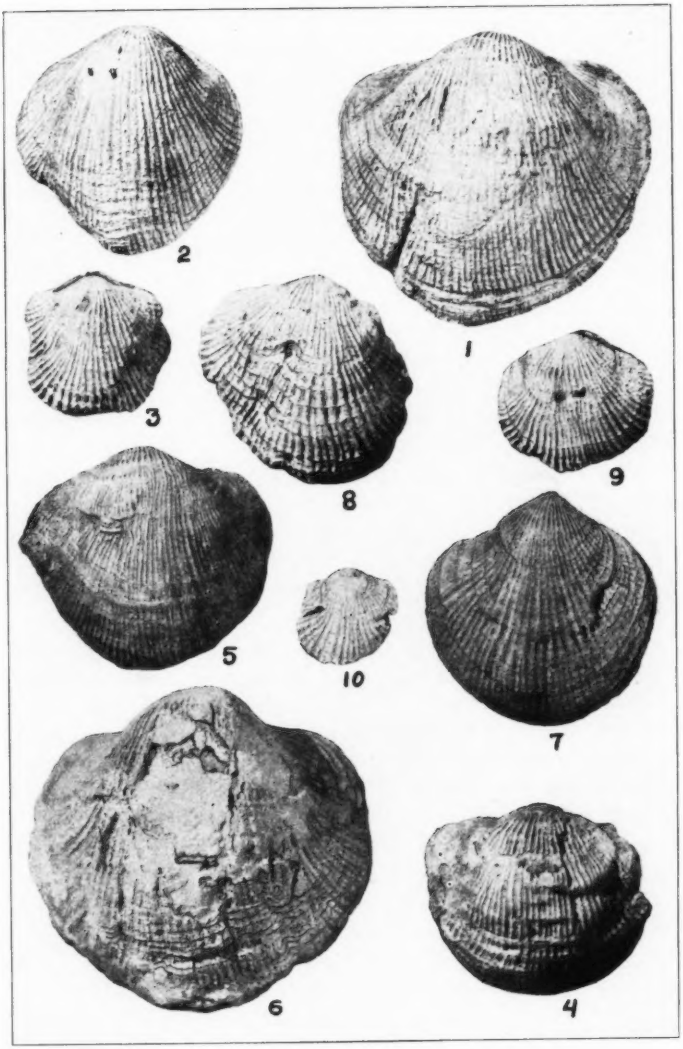
5. *Atrypa* sp., undescribed, an early ephebic shell showing marked distortion of the brachial valve. Devonian (Cedar Valley), three and one-half miles south of Cedar Falls, Ia. (4775 Carnegie Mus.)

6. *Atrypa waterlooensis* Webster, var. undescribed. A large shell bearing numerous injuries inflicted by boring sponges and annelids which penetrated the shell near its margin. Devonian (Cedar Valley), South Waterloo, Ia. (4769 Carnegie Mus.)

7. *Atrypa nuntia* H. & W., showing apparent fracture of the shell as well as distortion. Devonian (Hamilton: Sellersburg?), Charleston, Ind. (4777 Carnegie Mus.)

8–10. *Atrypa waterlooensis* Webster var. undescribed; three specimens showing the symmetrical injuries common in this form. Devonian (Cedar Valley), Waterloo, Ia. (4770, 4773 and 4774 Carnegie Mus.)

PLATE X.



sediment, would fix the shell far more firmly than could the pedicle.

As has been indicated, the second type of injury or distortion probably grades into the first, in some cases involving constriction of the shell between adjoining objects. Such an explanation fails, however, to explain such paired injuries as those of Fig. 9, or the unpaired ones of Fig. 8. Perhaps they are to be compared with those of Fig. 6, in which the shell appears to have been injured, and the mantle damaged, by boring annelids. The cause of injury to the brachial valve shown in Fig. 1 is equally obscure.

Injuries of the first type, which involve fracture of the shell, can have resulted only from the sharp impact of foreign bodies. It seems improbable that other shells (generally brachiopods) associated with the *Atrypae* could cause such damage. The most available agents in the Cedar Valley limestones, as well as those of the Hamilton (Jeffersonville) are the larger "horn" corals, which seem frequently to have fallen over and lain in the mud. That such falling—or fallen—corals might break or distort growing *Atrypae* seems obvious; and none of the strata affording specimens for study give evidence of disturbance by waves or currents, which may account for damaged shells in some other formations.

A comment may be made upon the significance of alate lamellae in the attacks of boring organisms. To *Cliona*-like sponges, such lamellae probably would offer a barrier, since available evidence indicates that such sponges thrive best upon relatively smooth surfaces. For annelids, however, they would be just the reverse, offering both shelter for the thigmotactic worms, and footholds from which they might begin the process of burrowing. Several cases of entry between the bases of lamellae are shown in Fig. 6, and it is possible that the two borings shown in Fig. 2 were begun with similar shelter. In the latter case, it seems clear that the borings were not made until the shell had advanced considerably in both age and thickness, and so are in keeping with the conclusions already drawn as to orientation of the shell during ephebic and gerontic stages.

RECORDS OF AMPHIBIANS FROM THE EASTERN AND CENTRAL UNITED STATES (1931)

CHARLES E. BURT

The records of these collections were made in the summer of 1931 during an automobile tour through that part of the United States east of the Continental Divide. While engaged in this work, I was accompanied by May Danheim Burt, from whom I have received much timely assistance. Financial aid was extended from the University of Michigan and a large share of the specimens have been sent to the Museum of Zoology of that institution; the remainder has been deposited in the United States National Museum.

Records were gathered in 22 states and these states are listed here in the order of the number of new locality reports made available from each: New York (34), Nebraska (32), Georgia (14), Maryland (11), Wyoming (10), South Dakota (9), Vermont (9), Arkansas (9), Iowa (8), Alabama (8), Maine (7), Mississippi (7), Louisiana (6), Kansas (5), Florida (3), Wisconsin (3), South Carolina (2), Missouri (2), Connecticut (2), Illinois (1), Oklahoma (1), and New Hampshire (1).

LIST OF SPECIES

SALAMANDERS

Necturus maculosus (Rafinesque)

Mr. Ottys Sanders has recently given me a mudpuppy from Oshkosh, Winnebago County, WISCONSIN.

Amphiuma means Garden

A Congo eel with a tail 78 millimeters long and a body length of 240 millimeters was located on July 3 under a large log in the bed of a small stream 4 miles north of Baxley, Appling County, GEORGIA. There was no open water here but a supply of moisture was retained beneath the log.

Amblystoma tigrinum (Green)

A substantial series of large larvae of the tiger salamander were removed with a small seine from an open, algae filled,

stagnant pool 4 miles east of Pringle, Custer County, SOUTH DAKOTA, on August 11, where they were associated with *Rana pipiens* and *Thamnophis radix radix*.

After September rains, two adults were taken above the ground on the campus of Southwestern College at Winfield, Cowley County, KANSAS.

Plethodon cinereus (Green)

The redbacked salamanders in the present collection were all obtained between July 25 and July 28. As indicated below, females with sets of seven or eight eggs were rather common in favorable situations (damp rotted logs in deep woods) from Maine to upper New York state at this time. In each case the parent was disclosed in the vicinity of the rounded cluster of eggs, and in most instances it was curled about them. Individual egg masses were found to be attached to the roof of their respective cavities in the rotted wood by means of short whitish cords.

Specimens were secured in MAINE, 5 miles southeast of Naples, Cumberland County; and 2 miles northeast of Fryeburg, Oxford County (with one set of eggs). In NEW YORK, 7 miles east of Saranac Inn (with three sets of eggs) and 9 miles northeast of Tupper Lake, Franklin County; 2 miles north of Blue Mountain Lake (with one set of eggs) and 2 miles east of Raquette Lake (with one set of eggs), Hamilton County. In VERMONT, 7 miles west of Orange, Orange County.

Eurycea bislineata bislineata (Green)

These salamanders were common at the edge of the better aerated mountain streams, where they are found either free in the open water or on the banks, or where they may seek shelter under rocks, leaves or wood either above or below the water level. Individuals are more easily found and probably occur more abundantly in smaller flows of water than in the larger ones.

Specimens were collected in NEW HAMPSHIRE, 11 miles east of Crawford Notch, Carroll County. In NEW YORK, 4 miles southwest of Wilmington, Essex County, and on the western outskirts of Long Lake, and 2 miles east of Raquette Lake, Hamilton County. In VERMONT, 1 mile west of South

Ryegate, Caledonia County, and 4 miles west of Montpelier, Washington County.

Desmognathus fuscus fuscus (Rafinesque)

Both adults and young of this form were abundant along the algae-lined borders of a mountain streamlet 1 mile west of South Ryegate, Caledonia County, VERMONT. There were many alternate falls and pools in this brook, and investigation showed the larvae to be mostly in the pools where they sought concealment under small stones. The adults on the other hand were mostly in damp or wet situations under large rocks, particularly near or just below the waterfalls. Many examples of *Eurycea bislineata bislineata* were present in this same habitat.

TOADS

Bufo americanus Holbrook

Common toads were often found in damp situations in deep woods, especially near streams or rotting logs. Near Tupper Lake, New York, one jumped into a small stream and attempted to hide opposite a log at the water's edge, thus displaying tactics similar to those of *Rana pipiens*. The backs of Oswego County, New York, individuals are colored bright reddish brown in rather marked contrast to the less conspicuous blackish, gray, and brown hues usually displayed.

Specimens were also taken in ARKANSAS, 1 mile north of Lowell, Benton County. In MAINE, 2 miles northeast of Fryeburg, Oxford County. In MARYLAND, 4 miles southeast of Prince Frederick, and 5 miles southeast of Prince Frederick, Calvert County. In NEW YORK, 9 miles northeast of Tupper Lake, and 5 miles southwest of Tupper Lake, Franklin County; 12 miles south of Tupper Lake, in northern Hamilton County; Irondequoit Bay east of Rochester, Monroe County; 2 miles west of Central Square, and 5 miles west of Central Square, Oswego County.

Bufo fowleri Hinckley

An adult toad, which seems assignable to this confusing form, was collected in the woods on Mineshoe Island, in the Potomac River, 1 mile west of Cabin John, on the border of Montgomery County, MARYLAND.

Bufo quercicus Holbrook

The peep of this diminutive toad, which is usually repeated several times in a monotone, reminds one of the call of a newly hatched chicken. At night it is heard rather frequently from trees in certain areas of the Southeast, but such specimens are very hard to locate and secure—if they can be taken at all! The only example in the present series was found during a shower 8 miles west of Meridian, Lauderdale County, MISSISSIPPI, after its peeps had revealed its position in the wet grass beside an open roadside ditch that had filled with water.

Bufo terrestris Bonnaterre

The southern toad resembles the common *B. americanus* both in habitat selection and in general appearance. On July 1 many adults were singing from a roadside ditch near Meridian, Mississippi, after a rain. Young were common on the edge of streams both in the woods and under bridges. On the hot afternoon of July 3 many of these specimens were found near Augusta, Georgia, hopping about on the hot sand at the edge of a small stream, reminding me of an adaptation that I had seen carried forward to a much greater extent by *B. woodhousii* in Nebraska (see Burt and Burt, Amer. Mus. Novitates, no. 381, 1929, p. 3).

Specimens were obtained in ALABAMA, 6 miles northwest of Ariton, and 2 miles south of Brundidge, in Pike County; and 3 miles southwest of Coatopa, Sumter County. In FLORIDA, 2 miles east of Chattahoochee, Gadsden County. In GEORGIA, 1 mile west of Naylor, Lowndes County; 8 miles southwest of Augusta, Richmond County; and 1 mile north of Lyons, Toombs County. In LOUISIANA, at Lutcher, St. James County. In MISSISSIPPI, 8 miles west of Meridian, Lauderdale County. In SOUTH CAROLINA, at Greenville, Greenville County.

Bufo woodhousii Girard

This species is common in favorable habitats in the Middle West, even in the open prairie regions where trees are few or absent. At about seven o'clock on the cloudless morning of August 18, the sun was rapidly warming numerous exposed

sand banks near Antioch, Nebraska. Here, many distinct trails involving the two rather widely separated and far spaced elements of various pairs of tracks were noted on the surface of the sand, each trail leading to a tiny mound, where it ended. Digging revealed the fact that each of these shallow mounds held a partially grown toad. Thus several dozens were collected in a short time, both here and at other points. By eight o'clock most of the toads had left their respective holes in the sand. Although some were found hopping about, it was much harder to secure a series of the creatures after this hour. It is probable that after leaving its temporary larval home in shallow lakes and pools, the young sandhill toad migrates to the hillsides where it burrows into the sand at night and becomes inactive as the earth is cooled. In the morning it apparently awakes after the sand has been re-warmed by the sun, crawls to the edge of its temporary shelter, shakes itself, absorbs warmth producing energy, and then engages in a short diurnal pursuit of the insects upon which it preys. It would be of interest to learn just what the half grown sandhill toad does during the late forenoon and afternoon of the day, and also its behavior when it enters its sandy bed at night. Since individuals occurred in sand banks which were a significant distance away from the then existing bodies of water, it seems not improbable that these toads may remain permanently away from open water after they have emerged from it. This may be on account of some practical morphological or physiological adaptation which prevents rapid bodily loss of moisture.

Specimens were obtained in KANSAS, 4 miles north of Blue Rapids, Marshall County. In NEBRASKA, near the power plant at Valentine, Cherry County; 7 miles northeast of Crete, in Lancaster County; 4 miles east of Scotts Bluff, Scotts Bluff County; 2 miles east of Antioch, 2 miles east of Ellsworth, 3 miles west of Ellsworth, in Sheridan County; 1 mile south of Pilger, Stanton County. In WYOMING, 3 miles south of Greybull, Bighorn County; and on the banks of Hat Creek, 2½ miles north of the Hat Creek store, Niobrara County.

FROGS

Acris gryllus (Le Conte)

This plastic and well known species was taken in ALABAMA, 6 miles northwest of Ariton, and 3 miles northwest of Troy, in Pike County. In ARKANSAS, 1 mile north of Lowell, Benton County; 10 miles north of Ozark, Franklin County; 3 miles south of Delaney, Madison County; 1 mile west of Baldwin, Washington County. In FLORIDA, at Cypress, Jackson County; and 7 miles west of Tallahassee, Leon County. In GEORGIA, 1 mile west of Naylor, Lowndes County; and 1 mile north of Lyons, Toombs County. In IOWA, 1 mile southeast of Murray, Clarke County; 2 miles west of Albia, Monroe County; and 2 miles east of Ottumwa, Wapello County. In KANSAS, 2 miles north of Winfield, and 5 miles southeast of Winfield, Cowley County; and on the banks of Sandy Creek, a tributary of the Verdigris River, 5½ miles northeast of Coyville, in southern Woodson County. In LOUISIANA, 2 miles east of Mound,, Madison County. In MARYLAND, on Mineshoe Island in the Potomac River, 1 mile west of Cabin John, border of Montgomery County; and 1 mile east of Hyattsville, Prince Georges County. In MISSISSIPPI, 8 miles west of Meridian, Lauderdale County; and 2 miles east of Newton,, Newton County. In MISSOURI, 2 miles south of Asbury, Jasper County. In NEBRASKA, 1 mile northwest of Fordyce, North Logan Creek just north of Lowell, and 16 miles east of Randolph in Cedar County; 1½ miles south of Schuyler in ponds north of the Platte River, Colfax County; 4 miles north of Homer, Dakota County; 8 miles north of Fremont, Dodge County; and 1 mile south of Pilger, Stanton County.

Pseudacris triseriata clarkii (Baird)

The status of this subspecies, which appears to be sufficiently distinct from *P. triseriata triseriata* to be recognized as a valid taxonomic unit, is to be discussed in a separate report dealing with some amphibians and reptiles from Texas. A specimen at hand was taken in northern OKLAHOMA, 3 miles north of Ponca City, Kay County, where it was singing from a roadside ditch on May 30.

Hyla cinerea cinerea (Schneider)

Bell-frogs were captured at night on July 1 and 2, after their song had revealed their varied positions in brush, shrubs, and small trees near creeks and ponds. Specimens were collected in ALABAMA, 6 miles south of Ozark, Dale County; and 6 miles northwest of Ariton, in Pike County. In GEORGIA, 2 miles west of Homerville, and 4 miles west of Homerville, Clinch County. In MISSISSIPPI, 8 miles west of Meridian, Lauderdale County.

Hyla crucifera Wied

An adult of this species was captured 2 miles northeast of Fryeburg, Oxford County, MAINE, on July 25, after it was dislodged from its hiding place in a rotted log. A metamorphosing young individual was found on July 28, at a point 3 miles northeast of Old Forge, Herkimer County, NEW YORK, where it was emerging from a bog that was filled with sphagnum moss.

Hyla versicolor versicolor (Le Conte)

A very young tree-toad was found near Lake Sebago, at Raymond, Cumberland County, MAINE, on July 25. Singing adults were taken at night as follows. In ARKANSAS, from trees near a small pool 2 miles southeast of London, Pope County. In CONNECTICUT, from a tree in a meadow 2 miles west of Mystic, New London County, after a shower. In MARYLAND, on the ground near a pond 5 miles southeast of Prince Frederick, Calvert County; and on the rocks above the Potomac River off Mineshoe Island, 1 mile west of Cabin John, on the border of Montgomery County. In MISSISSIPPI, on the ground near a roadside pool 8 miles west of Meridian, Lauderdale County.

Rana catesbeiana Shaw

Bullfrogs are found in the region of larger ponds and streams. When disturbed they usually seek refuge in the deep water of their habitat, but they may go to the surrounding land for covering vegetation instead, especially at night.

Specimens were taken in ALABAMA, 3 miles northwest of Troy, Pike County. In ARKANSAS, 1 mile north of Ola, Yell County. In GEORGIA, 2 miles west of Homerville,

Clinch County. In IOWA, 2 miles east of Ottumwa, Wapello County. In LOUISIANA, at Estherwood, Acadia County. In MARYLAND, 5 miles southeast of Prince Frederick, Calvert County. In MISSOURI, 2 miles south of Asbury, Jasper County. In NEW YORK, at Raquette Lake, Hamilton County; and 2 miles west of Brockport, Monroe County. In NEBRASKA, 1 mile south of Niobrara, Knox County; and 3 miles southeast of Henry, Scotts Bluff County. In SOUTH CAROLINA, at Log Creek 6 miles northwest of Edgefield, Edgefield County. In VERMONT, 2 miles east of South Ryegate, Caledonia County. In WISCONSIN, at Oshkosh, Winnebago County.

Rana clamitans Latreille

Green frogs apparently do not always maintain the distinct dorsolateral fold on the sides of the body, and this character has been cited rather frequently as the chief criterion for separating the species from *R. catesbeiana*. Large series of green frogs from the localities in Louisiana and Wisconsin listed below, show complete transition between the presence and absence of these structures. Some examples have the fold anteriorly but not in the region just in front of the hind legs, while others have it only anterior to the forelimbs. Since the maximum size, voice, and, to a more limited extent, the typical habitats of *clamitans* and *catesbeiana* are so different, there is little doubt of the distinctness of the two. Better morphological distinctions between them than the maximum size and the character of the dorso-lateral fold should be sought.

Specimens were taken in CONNECTICUT, 2 miles west of Mystic, New London County. In GEORGIA, 2 miles west of Homerville, Clinch County. In IOWA, 2 miles east of Ottumwa, Wapello County. In LOUISIANA, at Estherwood, Acadia County, and at Lutcher, Saint James County. In MAINE, at Ocean View Park, near Wells, York County. In MARYLAND, 4 miles southeast of Prince Frederick, and 5 miles southeast of Prince Frederick, Calvert County. In NEW YORK, 4 miles northeast of Au Sable Forks in Clinton County; 5 miles southwest of Tupper Lake, and at the public camp site at Fish Creek Lake, 4 miles north of Wawbeek,

Franklin County; 1 mile south of Deerland, Hamilton County; 3 miles northeast of Old Forge, and 4 miles southwest of Thendara, Herkimer County; and 2 miles east of Lewiston, Niagara County. In VERMONT, 4 miles west of Montpelier, Washington County. In WISCONSIN, at Oshkosh, Winnebago County.

Rana heckscheri Wright

A young representative of this variant from *catesbeiana* was taken near the edge of a pool in a wooded section 1 mile west of Naylor, Lowndes County, GEORGIA.

Rana palustris Le Conte

This frog is commonly associated with *R. pipiens*, which is more common and widespread in the eastern United States.

Specimens were secured in the woods on Mineshoe Island, in the Potomac River 1 mile west of Cabin John, border of Montgomery County, MARYLAND; and in the grass and weeds near a pond 1 mile east of Middlesex, Washington County, VERMONT.

Rana pipiens Schreber

One of these frogs was removed from the stomach of a red-sided garter snake, *Thamnophis sirtalis parietalis*, 7 miles northwest of Wood Lake, Cherry County, Nebraska, but it was not preserved. Another individual was removed from the mouth of a prairie garter snake, *Thamnophis radix radix*, near Bassett, Nebraska, after its cry had attracted attention to its plight.

Specimens were obtained in ARKANSAS, 1 mile north of Lowell, Benton County; and 11 miles southeast of Maumelle, Pulaski County. In GEORGIA, 2 miles west of Homerville, and 4 miles west of Homerville, Clinch County; and 1 mile west of Naylor, Lowndes County. In ILLINOIS, 1 mile east of East Burlington, Henderson County. In IOWA, 1 mile southeast of Murray, Clarke County; 2 miles west of Albia, Monroe County; and 2 miles east of Ottumwa, Wapello County. In MAINE, near Lake Sebago at Raymond, Cumberland County. In NEBRASKA, 6 miles northwest of Ainsworth, Brown County; 5 miles north of Octavia, Butler County; 1 mile northwest of Fordyce, and North Logan Creek

just north of Lowell, Cedar County; bank of North Loupe River 10 miles south of Kennedy, 5 miles north of Simeon, and 9 miles northwest of Wood Lake, in Cherry County; 1½ miles south of Schuyler in ponds just north of the Platte River, in Colfax County; 4 miles north of Homer, Dakota County; 8 miles north of Fremont, Dodge County; 1 mile east of Hyannis, Grant County; 5 miles southwest of Bonner, Morrill County; 2 miles east of Bassett, Rock County; 3 miles southeast of Henry, and 1 mile south of Mitchell, Scotts Bluff County; 2 miles east of Lakeside, Sheridan County; and 1 mile south of Pilger, Stanton County. In NEW YORK, 1 miles northeast of Au Sable Forks, in Clinton County; Irondequoit Bay, east of Rochester, Monroe County; 2 miles east of Lewiston, Niagara County; 3 miles east of Vienna, and 1 mile south of Westernville at the edge of Delta Lake, in Oneida County; 1 mile west of Murray, Orleans County; 2 miles southwest of Hannibal, Oswego County; and on the western outskirts of Wallington, Wayne County. In SOUTH DAKOTA, along Battle Creek 1 mile southwest of Hermosa, 4 miles east of Pringle, and 2 miles north of Pringle, in Custer County; eastern outskirts of Belvidere, Jackson County; 5 miles southeast of White River, and on the banks of Little White River 1 mile west of the town of White River, in Mellette County; and 2 miles southeast of Caputa, and 4 miles southeast of Caputa, in Pennington County. In VERMONT, 1 mile east of Middlesex, Washington County. In WYOMING, 4 miles west of Douglas, 11 miles east of Glenrock, and on the eastern outskirts of Lost Spring, Converse County; 1 mile southeast of Torrington, Goshen County; 12 miles south of Buffalo, Johnson County; on the banks of Hat Creek 2½ miles north of the Hat Creek store, Niobrara County; 6 miles northwest of Dwyer, Platte County; and 1 mile southeast of Ten Sleep, Washakie County.

Rana sylvatica Le Conte

Woodfrogs were collected in Hamilton County, NEW YORK in the undergrowth near a small stream 10 miles northwest of Long Lake, and from damp shady places in woods 2 miles north of Blue Mountain Lake. Examples were

also secured in grass at the border of a small mountain brook, near the edge of the woods 1 mile west of South Ryegate, Caledonia County, VERMONT.

Gastrophryne carolinensis (Holbrook)

An example of this species from Lutcher, Saint James County, LOUISIANA, has a rough back like the one described for *areolata* in eastern Texas. Other individuals, which were taken 8 miles west of Meridian, Lauderdate County, MISSISSIPPI, sang from roadside pools after a rain on July 1. One call of this narrow-mouthed toad is loud and goat-like, but the other is only a soft murmur.

Southwestern College,
Winfield, Kansas.

AMMOBACULOIDES, A NEW FORAMINIFERAL GENUS

HELEN JEANNE PLUMMER

In the town of Webberville, Texas, about ten feet of dark and somewhat carbonaceous, fossiliferous shales of Navarro age are exposed along the left bank of the Colorado River. The stratigraphic position of this outcrop is approximately one hundred feet below the Navarro-Midway (Cretaceous-Eocene) contact. Gastropods are very frequent and present unmineralized shells.

The tough shale is rather resistant to the process of concentration for the study of microfossils. Thorough drying in a slow oven followed by several hours soaking, and finally boiling in a strong solution of sodium carbonate yields a mud sufficiently disintegrated to wash by the usual decantation process to a small residue rich in fragments of gastropods and pelecypods, *Dentalium*, *Cadulus*, echinoid plates and spines, otoliths, small irridescent shell fragments indicative of some cephalopod, frequent ostracods, and numerous foraminifera. The following foraminiferal forms have been identified:

Trochammina texana Cushman and Waters
Trochammina diagonis (Carsey)
Haplophragmoides excavata Cushman and Waters
Ammobaculoides navarroensis n. sp.
Reophax texana Cushman and Waters
Gaudryina rugosa d'Orbigny
Bulimina obtusa d'Orbigny
Neobulimina sp.
Heterohelix spp.
Gümbelina excolata Cushman
Gümbelina globulosa (Ehrenberg)
Ventilabrella carseyae Plummer
Lenticulina (*Robulus*) *navarroensis* (Plummer)
Nodosaria radicula (Linné)
Dentalina spinescens (Reuss)
Dentalina reussi Neugeboren
Uvigerina seligi Cushman

Ceratobulimina cretacea Cushman and Harris
Globotruncana arca (Cushman)
Globotruncana fornicata Plummer
Globigerina rugosa Plummer
Globigerina sp. (triserial, very high spired)
Anomalina pseudopapillosa Carsey
Gyroidina sp.
Epistomina caracolla (Roemer)
Epistomina cf. *elegans* (d'Orbigny)
Nonionella robusta Plummer
Spiroloculina sp.
Massalina cretacea (Reuss)
Quinqueloculina sp.

Family LITUOLIDAE

Ammobaculoides, nov. gen.

Genotype, **Ammobaculoides navarroensis** Plummer n. sp.

Description.—Test adventitious, elongate; early chambers arranged in a compressed coil, following chambers biserial and somewhat compressed, final chambers uniserial and uncompressed; aperture in first stage an arch at the base of the septal face, in the biserial stage an elliptical opening extending lengthwise of the septal face and reaching to the apex of the test, in the uniserial chambers terminal and round.

The distinctive character of *Ammobaculoides* is the biserial stage intermediate between the tight early coil and the uniserial series of full maturity. Both the insolubility of the test in acid and the positions of the apertures throughout growth link this form closely with *Ammobaculites*.

Ammobaculoides navarroensis n. sp.

Fig. 1, a-d.

Description.—Test elongate, composed of coarse angular quartz grains bound by an insoluble cement; early four to six chambers arranged in a prominent coil of about one complete convolution, next two to five chambers in biserial sequence and somewhat compressed, final chambers uniserial along a straight axis and uncompressed; aperture in coiled stage an arch near base of septal face, in biserial stage an elongate

ellipse extending toward the top of the septal face to the apex of the test, in uniserial stage round, large, terminal.

Length of holotype .63 mm.

Remarks.—*Ammobaculoides navarroensis* n. sp. is frequent at its type locality on Colorado River at the old ferry crossing in Webberville, Travis County, Texas. In general proportions this test is exceedingly variable, as are many arenaceous species. The limonitic filling of the early chambers, the transparent grains employed in the construction of the test,

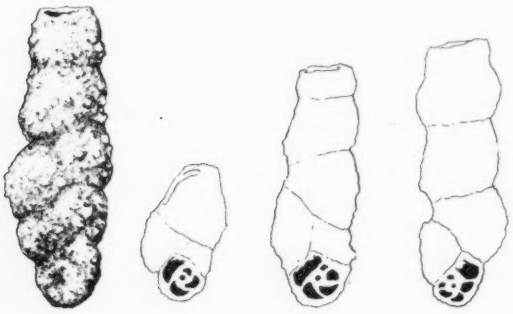
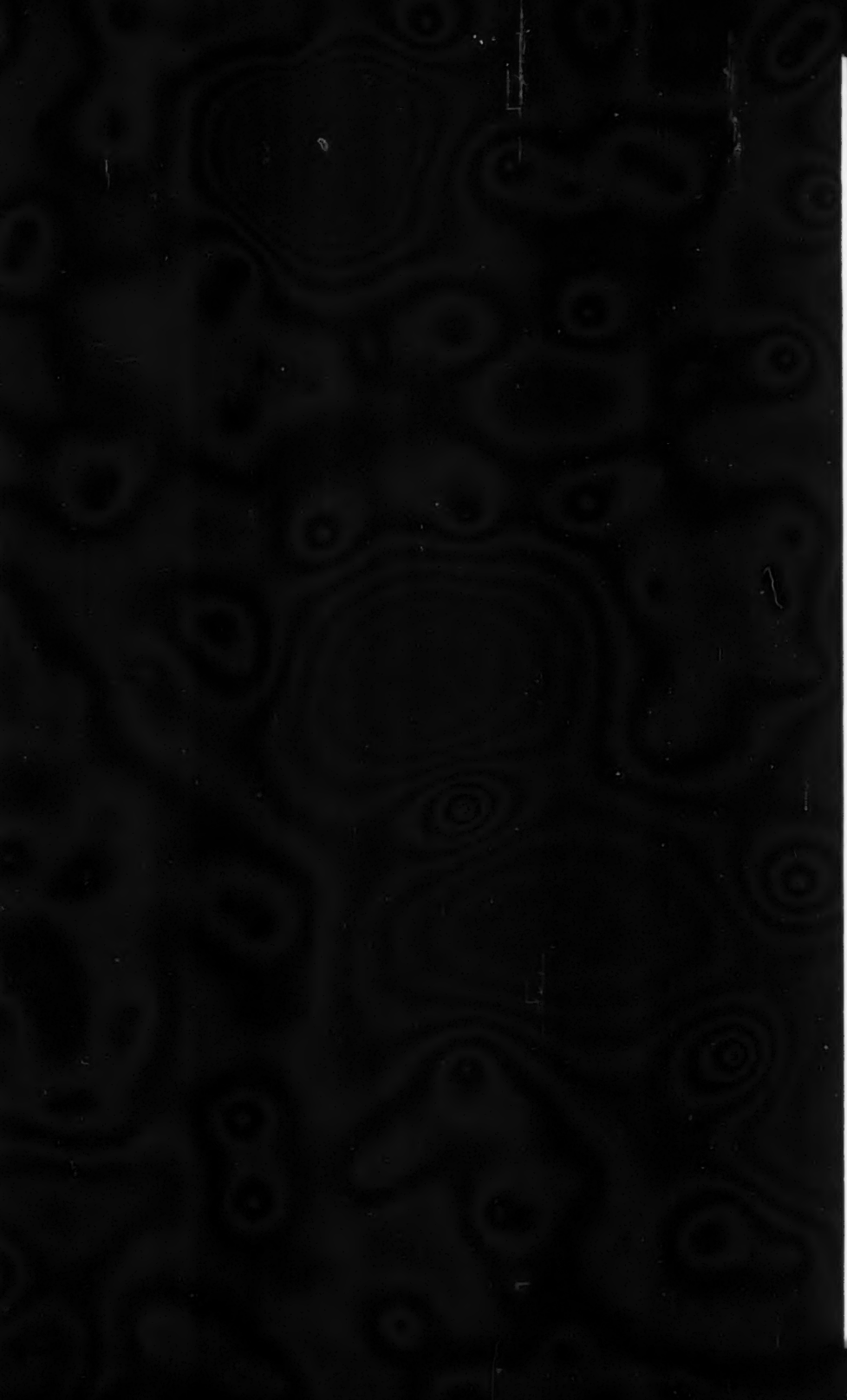


Fig. 1.

a. Side view of holotype of *Ammobaculoides navarroensis* n. sp.
b. Young form in biserial stage showing position of aperture. Early chambers visible in dampened test.
c. Specimen showing only three biserial chambers.
d. Specimen with two biserial chambers.

and the strong compression of this initial stage presents an excellent opportunity to study this portion of the test while it is wet with water or mounted in balsam. The proloculum of many specimens is clearly visible and shows considerable variation in size. No indubitable microspheric form has been identified. That all these tests are microspheric forms of some species that in the megalospheric generation would be either lacking in the initial coil or possess a much smaller coil is highly questionable. In the numerous samples of Navarro that have been examined no approximately similar test has been observed that could possibly be linked with *Ammobaculoides navarroensis* as its megalospheric test. Also the proloculi of all specimens at this locality are too large to be regarded as microspheric, and the following succession of chambers increase too rapidly in size for a microspheric sequence as we most commonly find it.



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